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A number of aspects of the relationships between characteristics of architectural space and science teaching methods in secondary schools were investigated using teacher questionnaire response and interviews for comparative facilities. Significant factors include--(1) the provision of classroom-laboratories, (2) proximity of the library, (3) size of laboratory sinks, (4) undeveloped outdoor areas, and (5) individual laboratory space. Discussion includes definition of hypothesis, listing of data, and extensive models, research design, and application and interpretation of results. Detailed information is provided on interviews, and data is given for fifty-nine schools in several states. (MM)

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ASPECTS OF SPATIAL INFLUENCE
ON
SCIENCE TEACHING METHODS

David Frederic Engelhardt

A Thesis Presented to the Faculty
of the Graduate School of Education
of Harvard University in partial
fulfillment of the requirements for
the degree of Doctor of Education.

1968

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PREFACE

This thesis is a sequel to the author's qualifying paper, "Space Requirements for Science Instruction: Grades 9-12." The qualifying paper presented and analyzed some key issues in the design of science facilities used by most science courses in grades nine through twelve. Not all aspects of these facilities for science education were discussed. The paper concerned itself with the immediate school environment -- where the student would study under the science faculty.

From a survey of the literature, the need for a comprehensive volume presenting the options of goals in science, various methods, and theoretical implications for school design was apparent. However, such a paper was still in the realm of logical opinion in two, completely different levels of theory. The first level of theory held that facilities do influence teaching methods, an assertion which many administrators questioned. This assertion has been taken as the "general hypothesis" in this thesis. The second level of theory involved many "specific hypotheses" which associated specific architectural design with definite instructional methods. This study investigates the extent to which evidence gathered on the specific hypotheses, taken as a group, might serve as evidence for the general hypothesis. The thesis is an attempt to gain empirical support for the rationale stated in the qualifying paper.

The research was made possible by the financial help awarded the author as a trainee under the Education Research Training Program of the United States Department of Health, Education, and Welfare. Additional funds for the majority of secretarial, travel, communication, and computer expenses were obtained from the General Electric Foundation Fund at Harvard Graduate School of Education and from that school's liberal underwriting of computer use. The author is greatly indebted to these sources of funds.

The cooperation of the superintendents, principals, science coordinators, science department chairman, and teachers was outstanding. Evidently, practitioners in the schools are extremely willing to help when they feel that research can yield answers or give guidelines to their pressing problems. Many thanks are due to those who willingly gave as much as several hours during the survey of their science department.

Other groups and individuals also participated in the introductory phases of the research -- namely the State Departments of Education in New Hampshire, Massachusetts, Connecticut, New York, and New Jersey, and the educational consulting firm of Engelhardt, Engelhardt and Leggett.

Through the planning stages and execution of the research, Harvard's personnel were available and often gave freely of their time in consultation. The ability to design the research rationale was undoubtedly a product of my general tutelage under Dr. Fletcher Watson, my faculty advisor. He and others of my thesis committee, Dr. Donald Davidson and architect Walter Hill, reviewed and gave valuable advice concerning the design and reporting of the research. Drs. Marshall Smith and Richard

Light lent specific advice and comment on the sampling and statistical procedures used during the study, although the author claims full responsibility for any procedural choice. Many decisions rested on background and advice given in research design courses and statistical courses given by Drs. Philip J. Rulon and Kenneth J. Jones. Through the latter, I became acquainted with the use of the computer. Invaluable instruction in the use of IBM equipment was given by Robert L. Stryker. Dr. Douglas Roberts, formerly on the Harvard faculty, deserves many thanks for his critique of the rationale presented in the qualifying paper. He spent many hours acting as an editorial advisor for the qualifying paper. Mrs. Sylvia Kovitz also gave her time as secretary to the department doing innumerable small chores and relaying messages to my home.

Mrs. Elisabeth Abrams has done an outstanding job as the typist for the thesis. Her ability to work from hand-written copy has speeded the publication of results.

The research has been a family affair. My father, Nickolaus L. Engelhardt, Jr., has given much advice as to the needs of practitioners in the field of school construction. His experience with educational research and in the fields of curricular and school building planning has made him my second "faculty advisor." My wife, Patricia, and our two children, Charlotte and John, have felt the day to day strain involved with a study of this magnitude. During the visitations I saw them only for thirty-six hours a week, over the weekend - even this time was mainly spent in thesis correspondence. The strain was lessened by having my home act as a message relaying center. The contact with them nightly compensated for the extra job given my wife. Without the home office coordinating secretarial work and messages, this survey could not have been done in four months. Throughout the design, execution, and reporting phases of this thesis, I have necessarily not had as much time as I would have desired for family activities.

To all these people and others connected with the research, I extend my deeply felt gratitude and appreciation.

David Engelhardt

Bureau of Curriculum Innovation

Massachusetts State Department
of Education

March, 1968

TABLE OF CONTENTS

Page

PREFACE. ii

LIST OF TABLES xi

LIST OF ILLUSTRATIONS. xiv

ABSTRACT xv

Chapter

I. INTRODUCTION: BACKGROUND FOR THE STUDY. 1

The Strategy of Research 3
  The selection of the topic 3
  The provision of a rationale 4
  Suggestions from practitioners 6
  Design and accomplishment of the research. 7
The Model Being Evaluated. 8
  Method of planning facilities. 8
  Assumptions inherent in the planning method. 10
    Inferred reverse model 10
    Selection of variables 11
      Accomplishment of goals. 11
      Method 12
      Facilities 15
        Influence on methods 15
        Spatial independent variables. 17
      Non-spatial independent covariables. 18
  Rationale. 22
    General hypothesis 22
    Specific hypotheses. 25
      Hypothesis one 25
      Hypothesis two 26
      Hypothesis three 28
      Hypothesis four. 29
      Hypothesis five. 30
      Hypothesis six 31
      Hypothesis seven 31
      Hypothesis eight 32
      Hypothesis nine. 32
      Hypothesis ten 33
      Hypothesis eleven. 33

Hypothesis twelve. 34
Hypothesis thirteen. 35
Hypothesis fourteen. 35
Hypothesis fifteen 37
Hypothesis sixteen 37
Hypothesis seventeen 38
Hypothesis eighteen. 39
Hypothesis nineteen. 40
Hypothesis twenty. 41

II. RESEARCH DESIGN. 43

Ex Post Facto Design Limitations 43
Sampling and Nomination Procedures 43
Interview Technique. 48
  Reason for the method. 48
    Persons involved 48
    Mode of data gathering 51
  The interview itself 52
Analytical Procedures. 54
Applications of Conclusions. 58
  Use of formal analysis 58
  Use of anecdotal remarks 62

III. REPORT ON THE INTERVIEW PHASE. 64

Trial Survey 64
Arranging Interviews 65
  Sequence of visitations. 67
Completion of Visits and Interviews. 73
  Absentees. 73
  Junior high visits incomplete. 74
Coding and Card Punching for Analysis. 75
  Code adjustments 75
    Periods per week, X(15) - X(16). 76
    Predominant organism, X(36). 76
    Cost of a lab period, X(8) 77
    Size of sinks, X(39) 78
    Average departmental budget, X(6). 78
  Card Punching. 78

IV. ANALYSIS OF DATA 80

Characteristics of the Sample. 80
  Statistical definitions. 80
    Skewness 81
    Kurtosis 81
    Normality test 82

Schools 82
  Average departmental budget, VAR(3). 83
  Budget per pupil, VAR(9) 83
  Cost per lab, VAR(6) 84
  Total college entrants, VAR(10). 85
  School enrollment, VAR(16) 86
  Mean years in department, VAR(21). 87
  Availability of late bus, VAR(65). 88
Teachers 88
  Subject experience, VAR(1) 88
  First course level, VAR(40). 89
  Second course level, VAR(41) 89
  Grade, VAR(42) 90
  Course subject, VAR(43). 90
  Laboratory-classroom relationship, VAR(47) 90
  Number of students in the laboratory, VAR(50). . . . 91
  Number accommodated in individual lab space, VAR(56) . . . 92
  Teacher has own classroom-laboratory, VAR(63). . . . 92
  Number of years in the system, X(10) 92
Dependent variable distributions 93
Specific Hypotheses. 96
  Hypothesis one 98
  Hypothesis two 101
  Hypothesis three 104
  Hypothesis four. 107
  Hypothesis five. 108
  Hypothesis five prime. 110
  Hypothesis six 111
  Hypothesis seven 113
  Hypothesis eight 117
  Hypothesis nine. 119
  Hypothesis ten 119
  Hypothesis eleven. 120
  Hypothesis twelve. 125
  Hypothesis thirteen. 127
  Hypothesis fourteen. 128
  Hypothesis fifteen 129
  Hypothesis sixteen 133
  Hypothesis seventeen 133
  Hypothesis eighteen and eighteen prime 135
  Hypothesis nineteen. 136
  Hypothesis nineteen prime. 137
  Hypothesis twenty. 139
General Hypothesis 139

V. CONCLUSIONS AND ANECDOTAL DATA. 141

General Hypothesis. 141
Specific Hypotheses 143
Hypothesis one (library usage). 143
Hypothesis two (wet inquiry lab modal). 147
Hypothesis three (cooperative assignments). . . . 149
Hypothesis four (lab team approach) 149
Hypothesis five (outdoor individual projects) . . 150
Hypothesis five prime (type of area -- projects). 150
Hypothesis six (type of outdoor classroom). . . . 151
Hypothesis seven (individual lab space) 151
Hypothesis eight (ninth grade biology). 152
Hypothesis nine (film showing). 153
Hypothesis ten (television) 154
Hypothesis eleven (central storage) 154
Hypothesis twelve (greenhouse). 154
Hypothesis thirteen (growth chamber). 155
Hypothesis fourteen (own room). 156
Hypothesis fifteen (sink size). 157
Hypothesis sixteen (optics exercises) 157
Hypothesis seventeen (undirected wet lab) 158
Hypothesis eighteen and eighteen prime (student access). 158
Hypothesis nineteen (teacher access). 159
Hypothesis nineteen prime (access-inquiry). 160
Hypothesis twenty (modal organism). 160

VI. APPLICATIONS AND INTERPRETATION 161

Educational Specifications. 161
Inquiry teaching. 162
Wet laboratory teaching 164
Miscellaneous methods 166
Use of the library. 166
Use of television 166
Showing of films. 166
Stimulation of individual projects. 167
Lower equipment and supply costs. 168
Optics experiments. 169
Consequences of Architecture. 169
Summary 170
A New Area of Research. 171

Appendix
A. THE INTERVIEW SCHEDULE. 173
B. VARIABLE LIST AND DEFINITIONS 192
C. KINDS OF LETTERS SENT TO ARRANGE INTERVIEWS 204
D. ANALYSES USED FOR CROSSBREAKS 213
BIBLIOGRAPHY. 229
VITA. 234

LIST OF TABLES

Table Page

1. Number of Schools Nominated by Each State. 48

2. Nominated Schools and Visitation Record. 69

3. Cost Per Laboratory, VAR(7). 85

4. School Enrollment, VAR(17) 87

5. Grade Distribution of Teacher Situations Producing Data 90

6. Teacher-Subject Frequency. 91

7. Frequencies of Teachers Using Certain Methods in Specific Courses and with Specific Levels of Students. . . 94

8. Contingency Table for Hypothesis One 99

9. Hypothesis One--Specified Crossbreaks. 100

10. Contingency Table for Hypothesis Two 102

11. Hypothesis Two--Specified Crossbreaks. 103

12. Contingency Table for Hypothesis Two Modified. 104

13. Hypothesis Two Modified--Specified Crossbreaks 105

14. Contingency Tables for Hypothesis Three. 106

15. Hypothesis Three--Specified Crossbreaks. 107

16. Hypothesis Four--Kolmogorov-Smirnov Test Frequency Comparison of X(46) Responses. 109

17. Contingency Table for Hypothesis Five Prime. 110

18. Hypothesis Five Prime--Specified Crossbreaks 111

19. Contingency Table for Hypothesis Six 112

LIST OF TABLES--Continued.

Table Page

20. Hypothesis Six--Specified Crossbreaks. 112

21. Contingency Tables for Hypothesis Seven. 113

22. Hypothesis Seven--Specified Crossbreaks. 115

23. Contingency Table for Hypothesis Eight 118

24. Hypothesis Eight--Specified Crossbreaks. 118

25. Contingency Tables for Hypothesis Nine 120

26. Parametric Tests for Hypothesis Nine 121

27. Hypothesis Nine--Specified Crossbreaks 122

28. Contingency Table for Hypothesis Ten 123

29. Hypothesis Ten--Specified Crossbreaks. 124

30. Contingency Table for Hypothesis Eleven. 123

31. Hypothesis Eleven--Specified Crossbreaks 126

32. Contingency Table for Hypothesis Twelve. 125

33. Hypothesis Twelve--Specified Crossbreaks 127

34. Contingency Tables for Hypothesis Thirteen 128

35. Contingency Table for Hypothesis Fourteen. 129

36. Contingency Table for Hypothesis Fourteen Using Lab Centered Variable. 130

37. Hypothesis Fourteen--Specified Crossbreak Using Lab Centered Variable. 131

38. Contingency Table for Hypothesis Fifteen 131

39. Hypothesis Fifteen--Specified Crossbreaks. 132

40. Contingency Table for Hypothesis Sixteen 133

41. Hypothesis Sixteen--Specified Crossbreaks. 134

LIST OF TABLES--Continued.

Table Page

42. Contingency Table for Hypothesis Seventeen. 134

43. Hypothesis Seventeen--Specified Crossbreak. 135

44. Contingency Table for Hypothesis Eighteen 136

45. Contingency Table for Hypothesis Eighteen Prime 136

46. Contingency Table for Hypothesis Nineteen 137

47. Hypothesis Nineteen--Specified Crossbreaks. 138

48. Contingency Table for Hypothesis Nineteen Prime 138

49. Summary Results of Specific Hypotheses. 140

50. Significant Findings of the Specific Hypotheses 144

51. Maximal Values for C. 218

LIST OF ILLUSTRATIONS

Figure Page

1. The Procedural Model for Drafting Educational Specifications. 8

2. The Inferred Reverse Model Demonstrating Underlying Assumptions of the First Model 10

3. Schematic Crosstab Key. 214

ASPECTS OF SPATIAL INFLUENCE ON SCIENCE TEACHING METHODS

by David F. Engelhardt

Abstract

The existence of associations between characteristics of architectural space and science teaching methods in secondary schools was investigated. Exemplary science departments from New Jersey, New York, Connecticut, Massachusetts, and New Hampshire were included in the sample. Only science departments occupying facilities built or renovated since 1960 were considered for nominations. By interview technique, 496 teachers in 59 high schools (or associated junior high schools) were questioned regarding their teaching practices. Responses were statistically compared with the facilities available to the responding teachers. Most teachers were given individual thirty minute interviews in the spring of 1967. Characteristics of architectural space were found to be significantly associated with certain teaching practices. This finding should emphasize the necessity for proper drafting of educational specifications.

Since specific hypotheses were reasoned prior to gathering empirical data, a causal connection between architectural design and science teaching practice was suggested where a significant association was verified statistically. Other interpretations were acknowledged; nevertheless the highly significant findings, which may serve as empirical guides for future design of school science facilities, have validity regardless of their interpretation.

Associational measures were consistently weak, with some improvement manifested when contingent conditions were specified. The main method of testing the null hypotheses was by non-parametric analysis. Crossbreaks were presented first without specification of contingent conditions and then with up to three specifiers regarding non-architectural characteristics. Anecdotal remarks were not fully analyzed and did not influence the testing of originally stated hypotheses.

Twenty specific hypotheses were evaluated. Classroom-laboratories were found to be associated with wet inquiry methods, proximity of the library with usuage, large sink size with higher frequency of laboratory periods in biology and earth science, undeveloped outdoor areas with outdoor problem solving, and individual lab space with frequency of individual projects. Central storage was associated with higher cost per lab period in small schools and with lower cost per lab period in schools over 1,000 pupils. Greenhouses did not stimulate much experimental work with plants. Except for energetic junior high school teachers, senior high school biology teachers tended to be inquiry oriented more often than ninth grade biology teachers housed in junior high facilities. Convenient after-hour access by teachers to laboratory facilities was associated with more lab work when classes had the usual time allowance for lab. Sunlight can be considered more a contaminant than an aid in science facilities.

Scheduling and other administrative procedures had deep influence on inquiry teaching. Subsequent publication of these results may be labeled as part of the Facilities Research Project.

CHAPTER I

INTRODUCTION: BACKGROUND FOR THE STUDY

The design of facilities for science instruction has been of deep concern to school administrators and architects. Despite the expense of laboratory construction and the recent stress on certain types of lab-centered science teaching, little has been written which can allow administrators and architects to decide among the various possibilities for laboratory design. This study addresses itself to those who wish empirical studies of some opinions in science facility design. Such opinions and supporting theory are presented in the author's qualifying paper,[1] which reviewed various instructional methods in science and presented some specific propositions about the influence of the design of secondary school science facilities.

The major concern of this thesis is to evaluate the plausibility for the hypothesis which justifies concern for the design of schools. This general hypothesis, stated in alternative form, reads -- the characteristics of architectural space significantly influence a teacher's basic methodology of science teaching. Most architects and educational consultants assume the general hypothesis to be true, but many school administrators are skeptical. If one does believe that such a relationship exists, then more specific questions arise. Finding answers to them is the secondary purpose of this study. Taken as a group, the specific hypotheses (which were generated from specific questions) should form a basis upon which to evaluate the general hypothesis stated above.

---

[1] David F. Engelhardt, "Space Requirements for Science Instruction: Grades 9-12" (unpublished qualifying paper for the Ed. D., Graduate School of Education, Harvard University). A copy of this paper is available on interlibrary loan from the School of Education Library, Harvard Graduate School of Education, Appian Way, Cambridge, Massachusetts 02138. One should ask for "Space Requirements for Science Instruction: Grades 9-12" by David Engelhardt, series -- Qualifying Paper, October 1966.

In the various sections to come, it will be apparent that the Facilities Research Project[1] has been conducted with a desire to yield practical information for practitioners in education and architecture. In some aspects, such as sampling, adopted procedures are not generally valid for most investigations. Such procedures are used to avoid anticipated objections from those administrators who may be reluctant to adopt the conclusions of this study. Although this statement may appear to show prejudice on the part of the investigator, the effort made in being an impartial data gatherer is apparent from the interview analysis -- many null hypotheses were not rejected.[2]

---

[1] Facilities Research Project is a collective term for this study including papers to be forthcoming.

[2] Anecdotal remarks were not included in the statistical analysis for this paper; subsequent reports may show rejections of null hypotheses when new specifying conditions are added.

The Strategy of Research

The Selection of the Topic

Why was the influence of architectural space[1] on science teaching methods chosen as a subject for investigation? In the field of educational research, new funds have been made available for research in problems close to the classroom and for application of research findings. Although these problems may not allow tight experimental design, this study attempts to demonstrate a fruitful exploration of a strong hypothesis which may appear to be statistically supported even without all pertinent variables being controlled. From acquaintance with the educational consulting firm of Engelhardt, Engelhardt and Leggett, it was apparent that disagreement existed among educators about the most appropriate design options for instructional facilities in science. Because the question seemed almost unexplored by any sophisticated research, it appeared that any answers would be welcome.

The selection of this topic for study did not involve the assumption that characteristics of architectural space were the major determinants of teaching method. The premise was that, under certain circumstances, facilities are the deciding factor in conscious decisions of teachers and are a subtle influence during the formulative stages of teaching plans.

---

[1] For an extended discussion of the term "architectural space" see -- David Engelhardt, pp. 2-5.

The Provision of a Rationale

The rationale for the study was developed during several months and appeared as an independent volume[1] before the data gathering was planned. This sequence of research gives greater strength to conclusions based on ex post facto research or survey techniques. There is less chance of predicting spurious relations existing in an unknown sample, whereas finding spurious relations after gathering data is more likely when no limit is placed on the null hypotheses entertained.[2] The importance of a predicted correlation of .01 significance should be greater than a correlation of the same significance and magnitude found without prediction. The fact that a theory could lead to the same relationship as found in nature lends more credibility to functional relations between two variables. Such a characteristic in design is advantageous to studies -- this study being an example -- which have tenuous causal interpretations because of their ex post facto nature. In this study relations are formulated after gathering data for one procedure; this is the selection of non-architectural factors[3] for specifying conditions under which spatial factors become limiting.

The qualifying paper approached the topic of architectural design by outlining several examples of instructional goals that could be chosen for science teaching. The paper pointed out that not all such goals could be accomplished, even partially, in one year and went on to urge planned articulation of courses with various goals. A conclusion was reached that the least costly, but still effective, building would have different facilities for the various course goals. Methods were reasoned from goals[1], and educational specifications were then given with four basic determinants in mind:

---

[1] David Engelhardt, the qualifying paper.

[2] The word "entertained" is used to replace "tested" since, in this instance, the sequence precludes testing -- other than a mathematical test of significance.

[3] Hereafter referred to as "non-spatial factors"; spatial factors on the other hand pertain to architectural space.

1) gross activities and sub-group organization;
2) number of students in the space;
3) services, for example: gas, ventilation, lighting;
4) location within the school and, to a lesser extent, the site upon which the school is built.

The qualifying paper noted two emergent issues involved with the discussion of the model drafting procedure[2] for educational specifications of school science facilities: 1) Are facilities a limiting factor in permitting certain instructional methods to be employed? If so, under what conditions does the architectural space become the limiting condition? 2) Does the presence of some obvious architectural facility suggest a certain instructional method?[1]

---

[1] Some research on the effectiveness of methods to accomplish these goals was presented; but, in the main, the lack of educational measurements left to administrators the decisions among theories.

[2] Infra, p. 8

This thesis does not engage in a sophisticated study of the second issue: suggestiveness of space. This study is limited to examining the degree to which facilities are correlated with teaching methods and to specifying conditions where space may limit teaching procedures.

Suggestions from Practitioners

The last step in the rationale, reasoning from methods to appropriate facilities, is tested here with empirical survey data. Specific statements from the qualifying paper were selected for investigation. A few hypotheses were added later from suggestions made by practitioners in school building design.

With the aid of these practitioners, twenty hypotheses were chosen from over ninety statements in the qualifying paper asserting relations that might be examined by survey methods. Two criteria formed the basis of selection:

1) Could the hypothesis be tested within the duration and circumstances of this study?
2) For the school designer, was knowledge about a certain relationship important?

Hypotheses selected did not have to meet both criteria. From this standpoint, the various hypotheses have varying degrees of importance -- from a study relating size of sinks and amount of lab work, to a study of the effect of having separate laboratories and classrooms on the tendency to use inquiry methods.

---

[1] An example of the suggestiveness of space might illustrate the concept sufficiently without reference to the qualifying paper (David Engelhardt, pp. 7-9, 85-88): The presence of individual laboratory cubicles might stimulate the undertaking of individual projects.

Design and Accomplishment of the Research

Following the selection of hypotheses, the research was designed with the aid of faculty members versed in statistics, sampling theory, and factors influencing science teacher behavior. The interview schedule was formulated, critiqued, and tried in a few schools in eastern Massachusetts. While a final form of the interview schedule was being made, requests for nominations of schools to be included in the survey were being answered.

At first, schools were visited in the order which visitation permissions were obtained. As the list of schools became larger, areas were visited to minimize travel expenses. From March 1967 until mid-June 1967, the author gathered data through individual interviews with teachers. Data were then transferred to punch cards, and analysis was accomplished using Harvard's computation facilities. Anecdotal remarks remained on file for interpretation at a later time. A report to participants and several journal articles are to be published in order to fulfill the practical aims of the research.

Except for final editorial work, the aspects of the Facilities Research Project reported in this thesis took a busy seven months of full time work. Total expenses for travel, communications, and secretarial work[1] amounted to $2500. An estimate of useful computer time[2] was sixty-nine minutes. Three months were spent in writing the original draft of this thesis and in analyzing non-anecdotal data.

The Model Being Evaluated

Method of Planning Facilities

N. L. Engelhardt and others have found that communities are most satisfied with school building programs when the initial planning phase has been based on the "statement of philosophy" under which the school would operate.[3] After the basic purposes and goals have been recognized, the planning process continues with the next areas of concern.

> The curriculum and the general methods of instruction that will be followed are discussed at length. Class sizes are defined, the teacher and pupil needs are outlined and the space requirements are fully set forth.[4]

This procedural sequence for drafting educational specifications may be represented by the model in Figure One.

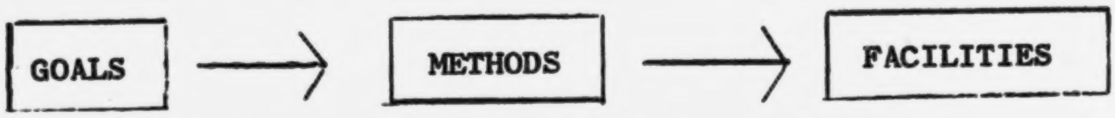

Fig. 1 - The procedural model for drafting educational specifications.

---

[1] Secretarial work does not include work connected with the preparation of the thesis proper. Of the above total cost, $150 was attributable to secretarial work.

[2] Later sections specify the programs and model of computer used.

[3] N. L. Engelhardt, N. L. Engelhardt, Jr., and Stanton Leggett, School Planning and Building Handbook (New York: F. W. Dodge Corp., 1956), p. 5.

[4] Ibid.

The major premise of the model is that the educator who knows the goals and intended instructional methods of the school system can participate effectively with the architect in shaping the educational space within the classroom and on the school site.

Use of the model produces educational specifications which are highly flexible in the actual process of designing schools. The architect knows the basic educational needs and goals; this knowledge enables him to modify specifics as the building plan develops. As a consequence, fulfillment of the educator's desires is not so dependent upon other design features. By utilizing the model and the four basic determinants of spatial adequacy,[1] the educator becomes a more effective contributor to the final school plan than does one who only requests specific architectural items.

When educators are aware of the basic goals inherent in the use of various methods, achievement of economy and efficiency for the total school program is possible. The expense of laboratory facilities may or may not be justified after examining basic goals. The model might stimulate teachers and science educators to look for alternative requirements for many objectives which formerly had only one method of being accomplished. The introduction of newer, more efficient methods of teaching -- from the use of growth chambers to computerized teaching machines -- will be aided by a thorough analysis of goals, methods, and facilities. The model suggests such analysis.

---

[1] Supra, p. 5. The four basic determinants are mentioned throughout the qualifying paper, David Engelhardt, pp. i-ii +.

Assumptions Inherent in the Planning Method

The qualifying paper[1] was a demonstration in the use of the model in Figure One; this demonstration raised issues which have led to the present research and could lead to new insights in the realm of school design.

Inferred reverse model

The model expressed in Figure One involves several important assumptions which become evident when the model is reversed as in Figure Two.

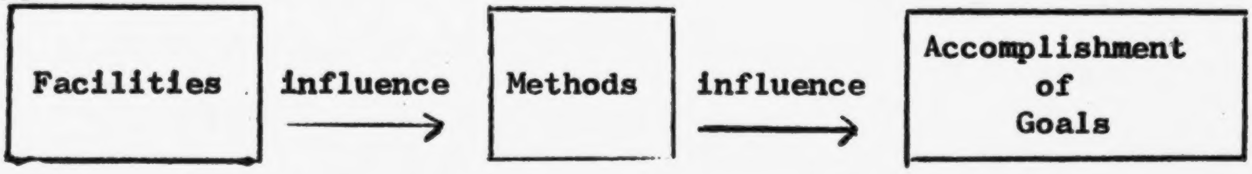

Fig. 2 - The inferred reverse model demonstrating underlying assumptions of the first model.

The reversal of the model is a method of revealing the justification for the recommended procedure for drafting educational specifications. Such justification would claim that methods do influence goals (assumption one), facilities do influence methods (assumption two), and that facilities influence the accomplishment of goals through an indirect influence on methods (assumption three). If one wishes to test the model, the assumptions might also be tested. Does the operation of schools appear to support the contention that this method of planning schools is justified?

---

[1] David Engelhardt, pp. 10-79.

Selection of variables

If one examines the variables in the reverse model, it is apparent that an investigation could measure facilities, method, and the accomplishment of goals. The reasons for selecting only a portion of the model for empirical examination are given below.

Accomplishment of goals

Since the main objective of our school system is to accomplish their instructional goals, it might have made most sense to evaluate the effect of facilities on accomplishment of goals (hereafter referred to as "accomplishments"). Since others have been attempting to measure the influence of methods on accomplishments[1] and have not succeeded in evaluating many important educational outcomes, it seemed legitimate to leave this field of endeavor for large scale efforts outside this thesis. These efforts will depend upon the development of new measurement techniques and improved instruments. It is therefore assumed that instructional methods do influence accomplishments. This thesis does not concern itself with assumptions involved between specific methods and certain goals. If a general relationship between methods and goals is acknowledged, then attention to what methods are employed is justified. If a factor influences methods in general, then study of that factor is justified.

---

[1] David Engelhardt, pp. 21-47, 98-108. In this reference, a review of method research is given as an example of information and theoretical foundations now available to aid policy-setting administrators in choosing appropriate methods.

If accomplishments are presently too difficult to measure for comparison with methods, direct comparison of facilities and accomplishments would be equally impractical.

Method

In this study, teaching method is not taken as an independent variable, but as a dependent variable. A wide variety of methods were selected with considerable diversity in importance. Diversity in answers for the various teaching methods indicated that teachers were not reluctant to answer candidly.

Teachers inevitably use a combination of methods and techniques. This research attempted to classify a teacher's technique by his tendency to adopt certain methods. His modal technique, his most used method, was generally taken as his answer for interview questions. In other instances he was asked if he had ever used such a technique this year. This procedure in measuring the dependent variable will introduce error, but with a large sample it was assumed that answers would tend to be valid -- with errors in responses balancing each other when the teachers actually taught predominantly in another manner. When given choices of two methods, teachers may have answered that both methods were used equally. A forced choice was used to reveal the tendency or at least to randomize the error. Such a design might yield low, but significant, correlations. These correlations might improve in magnitude if anecdotal remarks were used to eliminate the responses of teachers having to make close decisions.

In order to construct questions which seemed valid and proper, experience in teaching and awareness of the various views in science education were needed. Certain contrasting methods were chosen to provide over-simplified descriptions of a teacher's instructional approach; this selection of certain methods involved an element of risk for the evaluation of the general hypothesis since the selected methods might not have been closely associated with architecture. Value judgments were made when deciding how often a certain activity had to be done to accomplish goals inherent in each method.[1]

Since the laboratory is an expensive part of science facilities, a large portion of the teacher interview was based on a three-way classification of instructional methods for the laboratory phase of science courses.[2] The laboratory variations can be described by using three groups of adjectives: 1) wet-dry, 2) verifying-inquiring, 3) directed-undirected.

A wet laboratory occurs when actual apparatus, organisms, or chemicals are manipulated by the students. A dry laboratory occurs when vicarious methods are used to simulate wet lab or when data are gathered from a demonstration. Actual contact with the real subjects is avoided, but raw data could be given to students. Models can be used by students in place of actual materials. A film -- or televised experiment -- could also supply data. Students could ask computers or teachers, "What would happen if...," and the reply would supply the data as if an actual experiment had been performed.

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[1] A specific example where such a judgment may have been in error is where the teacher was asked if he usually used the class team approach in laboratory, students pooling their data rather than being autonomous individuals or small teams. Few teachers usually used the approach, but anecdotal remarks would probably show that this approach is used by many more teachers for a smaller, significant portion of time.

[2] David Engelhardt, pp. 23-24, 92-97 gives a full discussion and cites published examples of the various types of laboratory activities.

A laboratory experience is a verifying exercise when there is knowledge of the outcome or general trend of data prior to the experiment. The student is supposed to arrive at a foregone conclusion from his data -- the student could write the conclusion of his lab report before doing such an experiment. In the inquiring (or inquiry) laboratory, the answer is not known by the student before the analysis of data is complete. Data cannot be fabricated with certainty, although the experiment can be done with a prediction in mind.[1]

A directed laboratory is one in which the student is restricted in his activity by printed or verbal instructions. In the undirected laboratory activity, the student may be given a problem, but he must design his own experiment. Directed labs may blossom into undirected studies.

The options for laboratory methods, vicarious and otherwise, classified by the three characteristics mentioned above are as follows:

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[1] In physics, labs were considered inquiring if the student or class rigorously derived a relationship by mathematics before going into the laboratory to see if his calculations were correct. If the teacher demonstrated how the derivation was done, not giving the students a chance to function as theoretical physicists, the laboratory would be termed verifying. The approach -- theoretical or experimental -- that the physics teacher may adopt would be indicated by anecdotal remarks on the interview records. Both approaches reflect what physicists do today, which is one goal of the inquiry course.

1.	wet	verifying	directed
2.	wet	verifying	undirected
3.	wet	inquiry	directed
4.	wet	inquiry	undirected
5.	dry	verifying	directed
6.	dry	verifying	undirected
7.	dry	inquiry	directed
8.	dry	inquiry	undirected

The thesis is mainly concerned with each of the first four types and the last four as a group.

Facilities

Influence on methods. -- Facilities are but one possible influence on teaching methods. The existence of multiple factors makes it difficult to measure the influence of facilities, although the facilities themselves are easily measured. Rationale has been given[1], and predictive hypotheses have been made. The reasoning behind these hypotheses involves the claim that characteristics of architectural space limit or stimulate certain types of activities. The reader should be aware that this study cannot fully support a conclusion based on the above reasoning, since alternative interpretations could be equally plausible with ex post facto research.[2]

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[1] David Engelhardt -- The qualifying paper presented the rationale in full.

[2] For discussions reflecting the limitations and standard terminology of ex post facto research, the reader may wish to consult Fred N. Kerlinger, Foundations of Behavioral Research (New York: Holt, Rinehart and Winston, Inc., 1965), pp. 359-373 and Claire Selltiz et al., Research Methods in Social Relations (New York: Holt, Rhinehart and Winston, Inc., 1959) pp. 50, 65-78, 80-88. In some cases, alternative hypotheses

Without randomization or manipulation of students, teachers, and environments, the investigator can only gather circumstantial support for hypotheses -- increasing the plausibility of the hypothesis from opinion to an acknowledged phenomenon.[1] Of course, the potential consumers of this research could make use of a correlation, no matter what the causes of that correlation.[2] An example of an alternative interpretation is that teachers may be attracted to those facilities compatible to their methods of teaching. Either this interpretation or others cited in the qualifying paper will result in the same action during the design of the school building, and the methods used in that school would probably be the same.

In summary, although no causal connection can be inferred from the data obtained in the Facilities Research Project, the hypothesized relations between architectural space and teaching method will serve administrators and school designers. The finding of no correlation has

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can be examined in the same study. Nevertheless, control in ex post facto research is not as rigorous as in experimental investigations.

[1] If no significant correlation is found, the plausibility of the hypothesis is lessened. One cannot say the correlation does not exist in this case; the phenomenon may have been hidden by some unknown covariable not studied. Negative research (where the null hypothesis was not rejected) rarely proves anything. The support of null hypotheses is best left only as a statistical technique for verifying assumptions of distribution to meet parametric test requirements.

[2] If such decisions do not yield expected results, false hypotheses of causation can be modified with knowledge of failure conditions. In this situation, the consumer has been able to manipulate the environment and in the process has revealed another pertinent variable.

dubious interpretation -- a reason why negative findings should rarely be publicized. If correlations are found, more research should be considered. The ex post facto design is really an exploratory or descriptive phase of research. At present it is difficult to design controlled, experimental research in the area of architectural design.

Spatial independent variables. -- The term "facility" is often taken to include personnel and equipment outfitting the department (as indicated by the common usage of the phrase, "military facility"). This study concerns itself with large equipment items having bearing on original specifications for a new school and on the overall design of the science facilities. For this reason the architectural term "space" is often more appropriate than facility.

Each hypothesis and its variables differ in their significance for architects. In no way could each specific hypothesis be given a weight to be used for statistical inference to the general hypothesis. This inference must be made subjectively.

The spatial independent variables are indicated in the interview schedule located in Appendix A. Their answers have column code numbers forty-two through sixty-eight in the "Spatial Factor Assessment" section. Anecdotal remarks have indicated that some administrative procedures can also act as limiting architectural facilities. For instance, if students are scheduled for laboratory work in classroom labs in different groups or with different teachers, the occurrence of lab work is rarely flexible. With this administrative procedure, the situation is as inflexible as separate laboratory and classroom. Such complications have not been taken into account for analyses of hypotheses not predicting such procedures. Later reports will do so, but only informally.

Non-spatial independent covariables

If one assumes that the rationale does make the hypotheses tenable, the problem then becomes that of controlling the non-spatial variables so as to specify conditions under which space now becomes the limiting factor.[1] Absolute specification is obtained when a certain characteristic of space is the one factor determining whether or not a method is used. The goal of absolute specification is impractical, if not impossible when dealing with complex human actions -- it would set a statistical goal of $r = 1.0$ with no allowance for random error. Instead of electing such a goal, the investigator has tried to improve reported correlations or associational values by selecting a few pertinent non-spatial factors to be used as specifiers for conditions making the the influence of space more clear.[2]

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[1] The act of stating under what conditions a variable is a significant correlate is called "specification"; the conditions will be termed "specifiers" in this thesis. (See Kerlinger, p. 638.) With some variation in connotation, specifiers are called contingent conditions in Selltiz et al, p. 82.

[2] For instance, architectural influence is negated by budgetary reasons when money is not available for equipping laboratories. Even though some specifiers may be justified on correlational and logical grounds, their use is dependent on the number of teachers in that specifying condition. Even if specifiers with small sub-group populations had to be dropped from consideration, this method of specification is still legitimate. The legitimacy is due to the fact that this study is not investigating the logical network of non-spatial variables. Non-

Non-spatial variables will be discussed as they are used in the chapter on the analysis of data; variable selection and intent of use will be sketched here.

1) Information was obtained as to the number of years the teacher has taught the subject. It was thought that some variation might occur between young and experienced teachers; the former might be more willing to overcome obstacles and improvise. Since no dependent variable correlated with this variable, it was not used as a specifier.

2) Data on the average budget for the science department was also gathered — with surprising difficulty. Several systems did not keep separate accounts for their departments and great differences of reports from actual expenditures was anticipated. Such errors in reporting would conceivably scatter the distribution of cost per lab period. Unexpected agreement among schools regarding the cost per lab period suggests that science department chairmen and administrators outdid themsleves in obtaining accurate information. Various measures of financial support were calculated to make the measure more meaningful; these were cost per lab period and cost per pupil (total enrollment figure used).

3) Because the general tone of the school's curriculum might have bearing on instructional technique, the percentage of graduates going to

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spatial variables are used logically to raise correlations of spatial variables and instructional methods. This will hopefully aid decision-making under these various conditions.

To avoid the problem of small sub-group size, the technique of sampling would have to have been stratified. This was not possible since no readily available data gave information needed for such stratification.

accredited colleges was obtained on recent classes. Since the various guidance departments usually compute this statistic for other purposes in different ways, some schools could only give the percentage entrants into four year colleges or both junior and four year colleges (total entrants). The junior college percentage involved error since some figures had to be subjectively altered to account for technical schools and nursing schools. Oddly enough, junior college entrants often gave better correlations than total or four year entrants. Since using the variable of "total," rather than "junior," college entrants would yield eighty-two more teachers for analysis, the lower correlating variable was sometimes used to increase cell frequencies in analyses.[1]

4) Upon the suggestion of one school designer, the total enrollment of the school was investigated as a non-spatial variable.[2]

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[1] A high junior college entrant percentage may have indicated a school which was trying to upgrade the aspirations of its students and the community. The use of "total percentage" would mask the influence of this factor on instructional methods. If this factor is correlated with cost per lab, which serves as a dependent variable in one hypothesis, those schools supplying a junior college percentage could be keeping better records -- enabling better breakdown of expenditures and guidance statistics. Cost per lab (VAR 6, Appendix B) does correlate with junior college entrant percentage (VAR 13, Appendix B) significantly at the 0.01 level with $r = 0.406$.

[2] This is actually an architectural variable, but most other architectural considerations in this research were specifically of science facilities. Because of the interest expressed in this covariable, a brief report on its correlation is in order. The size of school (regardless of the number of grades included) did significantly correlate ($p < .01$) with opportunity to do undirected, wet laboratory experiments during class time or as assigned projects ($r = +.129$). It was used as a covariable with this method. Larger schools also averaged less cost per laboratory period ($p < .001$, $r = -.21$ with a maximum r less than one due to a skewed distribution).

5) General information about student time available for classwork was gathered. The number of double periods per week, single periods per week, and length of a single period served as variables and data. Various manipulations of these figures were used as non-spatial variables, such as total time spent in class and lab, number of single periods when no double periods were used, and total time of double periods. When modular scheduling was encountered, up to two modules (usually twenty to thirty minutes each) were counted as one period. Three and four modular periods were counted as double periods.[1]

6) The students in the teacher's classes were classified first as to introductory or second course and then as to rough ability -- high, average college, low terminal (first course only), and advanced placement (second course only).

7) Another non-spatial variable was the number of course preparations per day that a teacher had, including courses not germane to most of the dependent variable answers on the questionnaire. This non-spatial variable probably had significant correlations since it takes much time to prepare for a lab-oriented course.

8) For some dependent variables, the course subject would be a pertinent non-spatial variable. For instance, films may be more easily obtained for biology than for other sciences.

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[1] This resulted in some inaccuracy since a triple modular period was counted as a double period, whereas some schools had sixty minute single periods. This error was considered slight in the analysis. Anecdotal remarks would contain specific information for further analysis.

9) The modal grade for a course may be pertinent to some analyses. Instruction or help in library usage may not be needed every year in high school. Independent research may vary with the student's age, which is reflected in the student's grade level.

Appendix A indicates other information obtained, but not included in the final analysis nor in the proposal for research. In some cases, the information proved to have little correlational value; in other cases the variables were not intended for immediate analysis. The copy of the questionnaire is self-explanatory as to what information was collected.

Rationale

General hypothesis

If an educator assumes that activities within the school influence the child, the educator may then seek the causes of certain types of behavior in order that through understanding he may gain control of the influential activity. The obvious cause of most school activity seems to be student or teacher intentions; often the student responds to the teacher's wishes, which need not be voiced overtly. There are many factors which give rise to those intentions, such as training and past experience of the teachers, available time, readiness of the students, availability of equipment and tools, and general supportive nature of the environment. As a homely example of the last factor, rarely does one find a student drinking water where there is no access to water. (Here the lack of a facility serves as a constraint upon activity.)

Conversely, the presence of a water fountain may well suggest to the student a need for a drink. (Here a facility is doing more than allowing an activity to occur; it is suggesting the activity.) It is not the purpose of this thesis to distinguish between the suggestiveness and constraining influence of space; the data obtained reflects both influences.[1]

Another explanation for general spatial influence on actions can be based on a sociological analysis of the cost and gain for personal action. This explanation involves the assumption that for every action the actor is subject to a cost (for example, in effort, time, or respect) and a gain (for example, in savings of effort or time, in developing stature, or in student achievement.) The choice will be for that activity (or inactivity) which gives the most net gain or the least net cost.

Many architects and some educators[2] would agree with the assumption

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[1] While conducting the analysis, the investigator was alert for methods by which such distinction could be made in future research. Some methods may occur to the reader after reflecting upon some of the crossbreaks presented here.

[2] William W. Caudell, Toward Better School Design (New York: F. W. Dodge Corp., 1954), p. 24.

Council of Chief State School Officers, 1965 Purchase Guide for Programs in Science and Mathematics (Boston: Ginn and Co., 1965), p. 323.

Educational Facilities Laboratories, Inc., Design for Educational TV: Planning for Schools with Television (New York: Educational Facilities Laboratories, 1960) p. 5.

Paul DeH. Hurd, Science Facilities for the Modern High School (Monograph No. 2, Bulletin of the School of Education, Stanford University; Stanford, Calif.: Stanford University Press, 1954), p. 4.

W. E. Martin, "Report of Recorder for Group III -- Unresolved Issues and Problems in Science Education Research and Next Steps for that space can be a limiting factor[1] for instructional methods. For example:

> The educational plant is a means to an end. Its major contribution is to help create an environment which is most advantageous to the success of each child in accomplishing the desired learning outcome *planned* in the program on instruction.[2]

Drafting educational specifications in accordance with the model in Figure One and in accord with the above statement, demands much time on the part of educators. Some educators would disagree that this demand on their time is justified. These educators might object to placing the teaching environment in such a crucial position as a limiting factor. Possibly this reservation has contributed to the plethora of poorly prepared educational specifications. One of the purposes of this thesis is to test the assumption that facilities significantly guide the actions of teachers and stimulate the thoughts of students.[3]

NARST" *Science Education*, XLIV (February, 1960), 31.

National Research Council, *Guidelines for Development of Programs in Science Instruction* (Publication 1093; Washington, D.C.: National Academy of Sciences, 1963) p. viii.

John S. Richardson, *School Facilities for Science Instruction* (Washington, D.C.: National Science Teachers Association, 1961) p. 8.

Merle R. Sumption and Jack L. Landes, *Planning Functional School Buildings* (New York: Harper and Bros., 1957) p. 155.

[1] The biologist designates environmental factors which act upon the vital processes of an organism as "limiting factors." The state of one such factor when at a critical level is termed a "limiting condition."

[2] National Council on Schoolhouse Construction, *Guide for Planning School Plants*, (East Lansing, Michigan: National Council on Schoolhouse Construction, 1964), p. 1.

[3] A call for such research was given by C. W. Brubaker, "Relation of Learning to Space and Vice Versa," *National Association of Secondary School Principals Bulletin*, XLVI (May 1962), 197-200.

In null form, the general hypothesis can be stated:

> Characteristics of architectural space are not significantly associated with any instructional methods in science courses of grades nine through twelve.

Stated in alternative form:

> Characteristics of architectural space are significantly associated with some instructional methods in science courses of grades nine through twelve.

Specific hypotheses

The specific hypotheses, taken as a group, have bearing on the general hypothesis. However, each specific hypothesis does have value in its own right for use as feedback to school designers who feel that specific relations should exist. Designers have had little statistical feedback regarding their hypotheses. Below the rationale is briefly given for each hypothesis. A more complete and logical treatment is given in the qualifying paper.[1]

Hypothesis one

> Direct classroom or science department access to central library facilities does not significantly correlate with any class time being devoted to the use of the library.

A major architectural problem centers around the relationships between various instructional areas in the school. The library is an essential part of some instructional techniques. The theory leading to the alternative hypothesis[1] centers around two thoughts. First, a teacher may be more aware of the library and see the librarian more often if the library is adjacent to the department. The teacher could use the library immediately, when the need arose, by sending a student or group from a laboratory or discussion activity; most important, he would get his answer quickly. Second, if the library were far away, the teacher's class while passing in the halls could annoy other teachers conducting classes. Such annoyance would cause a loss of esteem from the teacher's colleagues, since he could not keep his class quiet on the way to the library. However, it was felt that teachers within the same department are probably more tolerant of each other, if only because they know each other closely.

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[1] David Engelhardt

Hypothesis two

The frequency of teachers using wet inquiry laboratory as opposed to any other method as their modal activity[2] does not differ significantly between separate laboratory facilities and combination classroom - laboratory facilities.

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[1] In this section all hypotheses will be stated in the null form. The alternative hypothesis form states that there will be a difference when a crossbreak is analyzed.

[2] Here, modal activity means at least one period per week in wet laboratory on the average for the year and introduction of a topic, rather than verification of a known relation, as the purpose of most of the labs. Introduction of a topic can only occur when students do not know the general relation being studied. Background for characteristics of an inquiry (or enquiry) laboratory can be obtained from Joseph J. Schwab, "The Teaching of Science as Enquiry," The Teaching of Science, jointly bound with a lecture by Paul F. Brandwein (Cambridge, Mass.: Harvard University Press, 1962), pp. 52-56, also 17, 24, 29 and 46.

This specific hypothesis is probably the most significant of any in this thesis. New science courses developed with financing by the National Science Foundation have tried to present science as an active, inquiring process where the student goes through some of the same intriguing types of laboratory endeavors as actual scientists.[1] This requires that answers be unknown before laboratory work is done and also requires that development of manipulative skills not be the sole purpose of every exercise. To enter into such an inquiry laboratory exercise, a student must be on the verge of hypothesis testing. If the lab is done too far ahead, the student sees no purpose in the lab and cannot exercise the skills that scientists employ. If the lab occurs even a day too late, the student will know the result as an accepted conclusion. The alternate hypothesis rests on the thought that unless the teacher has a classroom-laboratory (or vacant laboratory adjacent to the classroom), scheduling of an effective wet inquiry lab becomes nearly impossible. In many courses, several days of laboratory work are needed -- indeed several weeks with the Biological Sciences Curriculum Study Laboratory Blocks.[2] No scheduling of common laboratory

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[1] For a statement of the adoption of this goal by the NSF, see National Science Foundation, Science Education in the Schools of the United States (Washington: U.S. Government Printing Office, 1965), p. 26.

[2] These laboratory blocks are described in Biological Sciences Curriculum Study, Laboratory Blocks in Teaching Biology, edited by Addison E. Lee, David L. Lehman, and Glen E. Peterson (BSCS Special Publication No. 5; Boulder, Colorado: Biological Sciences Curriculum Study, 1967).

space would permit one teacher to use it for six, solid weeks.[1] Several national science courses have several days of lab work at the beginning, end, or during some common segment of the school year. When teachers share a common lab, demand for this space may become too great at these peak periods of laboratory utilization. It is therefore thought that the classroom-laboratory is far more flexible in critical timing than the separate laboratory facility. It was also felt that the environment of the laboratory would stimulate more laboratory work and more experimentally oriented thought.[2]

Hypothesis three

The number of cooperative teaching assignments[3] is not significantly greater than the number of solitary teaching assignments, in rooms having over fifty students versus rooms having fewer students.

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[1] One exception is noteworthy. Modular scheduling with open laboratories permits common laboratories to function with inquiry methods since no formal scheduling occurs.

[2] For a more detailed explanation of the rationale, the reader can refer to the questions in the interview schedule, Appendix A, and to the qualifying paper, David Engelhardt, pp. 14-16, 21-24, 34-37, 49, 54, 62. References outside of the author's writings include the following:

J. A. Campbell, "Chemistry -- An Experimental Science," The School Review, LXX (Spring, 1962), 55.

G. C. Finlay, "Physical Science Study Committee," The School Review, LXX (Spring, 1962), 70.

Paul DeH. Hurd, "The New Curriculum Movement in Science: An Interpretative Summary," The Science Teacher, XXIX (February, 1962), 9.

National Research Council, p. 7.

L. E. Strong, "Chemistry as a Science in the High School," The School Review, LXX (Spring, 1962), 46.

J. H. Woodburn and E. S. Obourn, Teaching the Pursuit of Science (New York: Macmillan Co., 1965), p. 369.

[3] A cooperative assignment is where two teachers meet with the class or lab at the same time. This does not include team teaching where various teachers meet with the same class at different times.

School designers have proposed that large rooms with two teachers might allow students more individual attention than small rooms with one teacher. Hypothesis three tests to see if such large rooms are used with two teachers or if there is a trend to increase class pupil-teacher ratio, thereby saving salary expenditures or relieving teachers for other duties. Two analyses were done: one where the teacher usually meets with the large class, another where the teacher infrequently meets with a large class, usually on a team teaching basis.

Hypothesis four

Laboratories taught by team methods[1] have the same distribution concerning number of assigned students as do laboratories taught by solitary methods.

A current architectural trend may increase the size of the typical laboratory by combining several classes under the direction of laboratory assistants.[2] Some teachers have found that solving problems as a class, through team research, not only reflects the current methods of research in industry and government, but also excites students and develops abilities necessary to function effectively as a researcher. The Biological Sciences Curriculum Study Laboratory Blocks are excellent examples of lab activities lending themselves to team research. Outdoor ecological surveys are also more easily done as team research. Hypothesis four is based on the assumption that the larger the group, the more difficult discipline becomes and the harder it is for each student to know what the other is doing. Safety considerations would probably encourage teachers to do a strictly directed lab exercise so that any student doing something unusual would stand out among the crowd. Large numbers in a laboratory might prevent teachers from taking several options in teaching methods.

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[1] The team method laboratory is where an entire class divides its effort on one large problem. Different groups investigate various aspects of the problem; at the end of the lab, data are combined. This does not include rotation of experiments to conserve equipment expenditures, nor small team effort where many teams are doing the same experiment with identical manipulation of variables.

[2] National Council on Schoolhouse Construction, p. 58, cites this trend.

Hypothesis five

The availability of an outdoor classroom is not significantly associated with the percentage of students doing individual projects. Hypothesis five prime (5') states that undeveloped outdoor areas are not significantly different than developed or landscaped outdoor areas in fostering individual projects.

Since physical room for experimental set-ups is often considered to be a limiting factor for individual projects, outdoor areas appear to be ideal for such work. Easy student access to the laboratory, after school time, would also be provided if students were doing outside work. Undeveloped areas could be more protected and less likely to have vandalism, since access would be difficult and projects hidden by natural cover. Furthermore, undeveloped areas might present a wider range of problems for student investigation.

Hypothesis six

The occurrence of at least one outdoor, inquiry study is not more frequent with those teachers having undeveloped areas for instruction as compared with those having only developed or landscaped areas.

The investigation of this hypothesis will reveal if teachers respond to opportunities on school sites. It was felt that problem-solving, inquiry studies could be done more easily in undeveloped areas. Other than using outdoor areas for inquiry, teachers could respond that: 1) they held only verifying nature walks, 2) they did not use the outdoors at all, or 3) outdoor work was not relevant to the course. The interviewer would automatically assume that outdoor areas could be relevant for introductory earth science and first year biology courses. Some advanced biology courses in anatomy and physiology or courses in non-biological disciplines could respond that it was not relevant, but such second courses were not common. The analysis will not include responses claiming irrelevancy.

Hypothesis seven

Individual study does not occur with different frequencies when spaces are available and when spaces are not available for retaining experimental set-ups.

Architects and educational consultants have long been advocating separate cubicles or areas where individual experiments can occur in undisturbed fashion. Hypothesis seven tests if such spaces are utilized and if they stimulate project work. Some analyses will omit responses of one hundred percent frequencies to avoid the dubious interpretation of compulsory, often poor quality science fair project work. Of course, other analyses will include such responses.

Hypothesis eight

There is no significant difference in the frequency with which wet inquiry techniques are practiced as the modal method in ninth grade biology when the class is given in systems having three or four-six year high schools.

A trend exists in science education that offers twelfth grade electives. For a student to take biology, chemistry and physics, this twelfth grade course often requires the science-prone student to take biology in the ninth grade. Because biology laboratory instruction often makes use of expensive ancillary facilities or outdoor areas, such facilities might be too expensive for junior high or middle schools to furnish for a small group of ninth grade biology students. Therefore, it was predicted that students taking biology in the ninth grade away from senior high facilities would get an impoverished inquiry lab program. This is particularly significant when one considers that the academically best science students get the impoverished program. The hypothesis tests to see if this is what is actually happening in schools.

Hypothesis nine

There is no significant difference in the frequency with which films are shown in classes normally meeting in rooms equipped for subdued light[1] and those providing no darkening whatsoever. (This was modified following trials to include a third, intermediate category, "poorly darkened," to give an ordinal scale.)

It was felt that the considerable effort involved in changing rooms for the showing of a film would deter a teacher from showing films. The poor quality of the image in a well-lit room would probably decrease the benefit students obtained from a film.

Hypothesis ten

Teachers having closed circuit television facilities use television no more than those using broadcast television.

One educational consultant wished to know if the expense of closed circuit television was "justified" by its use. It would appear that closed circuit operation offers much versatility through delayed broadcasting, showing of films in well-lit rooms, and in giving demonstrations to large groups. Broadcast television would seem to suffer from a lack of pertinence and difficulty in synchronization with class schedules.

Hypothesis eleven

In schools having more than one science classroom, there is no significant difference in cost per lab period for central storage compared to classroom storage.

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[1] This does not mean rheostat regulation of light. The intention of the phrase is to allow classification, under this option, of those rooms not having complete darkness, but where color films can be seen well. Color films were thought the most difficult to see.

The duplication of equipment because of artificial distinctions between subject areas and the tendency of teachers to hoard precious equipment could tend to raise departmental expenditures. It was suspected that centralized storage would eliminate the need for duplication of inventories in items such as chemicals, balances, glassware, ring stands, and glass tubing.

Hypothesis twelve

There is no significant difference in the modal use of plants for experimentation[1] when students have access to a greenhouse.

This hypothesis reflects the notion that greenhouses, especially economical ones, are too difficult to maintain and are generally in disuse. Furthermore, where greenhouses are in use, they are probably poor places in which to conduct an experiment. It is difficult to control conditions in a greenhouse. For better environmental control, artificial illumination can be used in place of sunlight for the growing of plants.[2] Data collected under this hypothesis could be used to support the recommendation that schools construct artificially illuminated growth chambers rather than greenhouses.

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[1] In other words, when plants are used in a course, are they mainly used for experiments? Modal use does not refer to all organisms used.

[2] Homemade growth chambers are urged as equipment in Arnold B. Grobman et al. BSCS Biology -- Implementation in the Schools (Biological Science Curriculum Study Bulletin No. 3; Boulder, Colorado: Biological Sciences Curriculum Study, 1964), pp. 21, 35.

Hypothesis thirteen

There is no significant difference in modal methods of dry lab demonstration versus wet lab when a movable, commercial growth chamber is available for use.

The tendency to rely upon a small commercial growth chamber for growing living plant material was thought to encourage demonstration or dry laboratory techniques since a class could rarely do all of its work in one expensive growth chamber. Various analyses were done since some chambers were present where a greenhouse or large homemade growth area existed.

Hypothesis fourteen

Teachers not having their own laboratory rooms do not teach differently regarding process-inquiry techniques as a modal method, in comparison with those who have their own laboratories.

It appears that many school designers have as a goal high percentages of utilization of space. As more teachers are scheduled in various rooms in order to increase room utilization, there may be significant reduction in the efficiency with which laboratory programs can operate. The heart of any inquiry or process centered science course is the laboratory. Any interference with conducting a large amount of laboratory will encourage teachers to revert to the less demanding product centered curriculum.[1]

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[1] Product centered curricula present the end products of research or the conclusions of scientific endeavor. Teaching is concerned with

Three general considerations indicate that having one's own room would facilitate inquiry teaching. First, the inquiry laboratory tends to be messy and often to have equipment left standing. This would annoy other teachers, especially non-science teachers, who would share the room. Often science teachers and assistants would like to clean desks and benches after a lengthy lab exercise which left no time to clean up during the period. One cannot do this if another teacher's class convenes in five minutes.

Second, logistics present such problems with inquiry lab courses that teachers must be well organized. If a teacher had to carry his orders, packing slips, lesson plans, experiment schedules, homework assignments, texts, and references under his arm from room to room, he would be less able to prepare for laboratory work. At the very least, an inquiry teacher needs his own desk in a room where he can work without annoying other teachers.

Third, the atmosphere of an inquiry class is extremely important. If science is to be presented as an act of inquiry, then examples of inquiring should permeate the room with the smells, sounds, and sights of experimentation. In desirable moderation these will not be obnoxious

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getting students to master a body of facts or concepts. This distinction between product centered versus process centered courses is discussed in the following references:

David Engelhardt, pp. 14-19, 21-45.

Joseph J. Schwab, "The Teaching of Science as Enquiry."

Oregon, State Department of Education, The Division of Education Development, The Structure of Knowledge and The Nature of Inquiry (A Report of the 1964 Oregon Program Workshop for The Oregon Program: A Design for the Improvement of Education; Salem, Oregon: State Department of Education, 1965), pp. 17-18.

for the students and teachers concerned with the activities. However, pressure from other teachers often prevents a laboratory from becoming a stimulating place in which to do science.

Hypothesis fifteen

The number of periods devoted to wet laboratory in earth science and biology is associated with the size of the largest sink in the laboratory.

This hypothesis was made part of the study in half seriousness. Nevertheless, the hypothesis was based on experience with small, inadequate sinks and with other teachers who complained that their students could not clean after labs because of a shortage in sink space. The hypothesis, if found to be rejected in null form, could show that even a small feature of lab design might influence a teacher's attitude toward lab work.

Hypothesis sixteen

When physics teachers are asked if they feel limited in the number and type of optical experiments, the frequency of response -- yes or no -- is not significantly different for those teachers teaching in rooms which can be darkened from those teaching in rooms with no (or inefficient) darkening equipment.

The use of the hypothesis evaluates an aspect of the general thought that sunlight is more of a contaminant, than a useful adjunct to science rooms. The use of skylights and large windows may be a significant fault in new science construction; the prevalence of this annoyance is being tested. The field of optics is being neglected currently in many physics courses, and possibly any architectural trends fostering this neglect should be revealed. Note that if the teacher does not desire to discuss optics, he is unqualified to answer "yes" in this question. The question attempts to reveal if the presence of light is a limiting factor, but any unconscious influence on the teacher to avoid optical experiments would reduce the correlation.[1]

Hypothesis seventeen

> The proportion of teachers having an undirected wet lab for most students at least once per year is not significantly different when groups of teachers are compared regarding the existence of centralized storage[2] in their science departments.

Although scientific research often depends upon improvising new tools, schools do make heavy, legitimate demands on those responsible for supplies and equipment. The logistics of undirected laboratories is the most difficult of supply problems since students may wish to use a wide variety of unanticipated equipment. Often this equipment is needed quickly or a class period, afternoon, week or month may be wasted while waiting for the equipment to be procured.

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[1] The question might have read, how many exercises do you conduct using optical phenomena as variables? This wording suffers from the problem of general disregard of optics in physics courses today.

[2] Centralized storage refers to a stockroom shared by teachers or lab assistants of chemistry, biology, physics and possibly earth science. Specialized equipment and specimens pertaining to one discipline may be stored in another room.

Possibly, access to a central supply of items would make a wide variety of equipment readily available to a student who may need tubing, a ring stand, a balance, or some other common item. The demand for several of the same items may come at the same time from one class; the central supply room could supply in quantity since items would not be thinly scattered throughout the department.

Hypothesis eighteen

After hour student access to facilities is not significantly associated with the frequency of wet lab methods as the modal teaching technique of those students' teachers. Hypothesis eighteen prime (18') concerns itself with the frequency of wet, inquiry lab methods under the same conditions of student access.[1]

The study of this hypothesis seeks information on the possible effect of designing security of buildings so that "honor" students could work on certain projects or maintain living organisms without teacher supervision. Scientific investigation does not result in convenient schedules. Vacation periods and weekends may be important work periods for some projects. Teachers, if not remunerated, should not be expected to devote extra hours to supervision of such projects. It was assumed that most schools would not pay teachers for this extra duty, and that despite liability laws, it appeared that a few schools were allowing students to work without supervision. It was hoped that the effect of this student access might influence general class curriculum as well as project work. The influence might be felt through the maintenance of living organisms for use in class.

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[1] After hour access also requires students to be unsupervised except possibly having a custodian in the building.

Hypothesis nineteen

After hour access to facilities by teachers is not significantly associated with the frequency of wet laboratory methods as the modal teaching technique. Hypothesis nineteen prime (19') states that after hour access to facilities by teachers does not significantly alter the frequency of wet, inquiry lab methods as the modal teaching technique.

With laboratory oriented courses, especially inquiry courses, teachers may have to devote long hours of preparation beyond normal school hours. The teacher may wish to choose his hours and not complete all preparation before going home from the regular school day. Often experiments need tending, or forgotten chores need to be done at odd times when custodians may not be around. Having to sign out a temporary key (or having to prearrange entrance with a custodian) does not allow a teacher needed flexibility. Rather than making a difficult job easier, refusal to issue keys to teachers, especially to new teachers, may make a lab-centered course nearly impossible to teach. The investigation of the hypotheses attempts to see if the above ideas are significantly accurate in reflecting the actual situation. Implications for architecture would involve separate security for the science department or at least separate security for some areas such as the vivarium.

Hypothesis twenty

There is no difference between frequencies of wet, dry, and no lab as modal activities[1] and process-inquiry techniques when biology teachers use one certain type of living organism for the majority of laboratory time.

This is the only hypothesis requiring a three variable crossbreak. The third variable, type of organism, is divided into microorganisms, plants, and animals as specified in the interview schedule.[2] The thought behind this hypothesis is that certain types of organisms are easier to handle in laboratory work. If one is designing ancillary biological facilities and cannot afford a microbiological chamber, an animal room, and a plant room -- which one would foster more experimentation? It was felt that animals are the hardest and most frustrating organism with which to work. It was also felt that microorganisms have not been used to their fullest possibilities, in part due to lack of teacher training in microbiology. Plant physiology experiments done by the author gave rise to the idea that plants are generally underestimated as "interest getters" in high school biology.

All of the above hypotheses were proposed before the final survey work began. Only a few were changed following the visits involving the trial interviews and these changes have been noted. Anecdotal remarks in the data files have led the investigator to modify some original thoughts, but such modification has not influenced the strict adherence to testing the original hypotheses. If additional correlational studies are done, this will be noted as an ex post facto hypothesis in the analysis section. Such hypotheses are only useful in that they suggest opinions to be tested in future studies.

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[1] If any lab is done, it should be classified as to whether it was wet or dry most of the time.

[2] Appendix A of this paper contains the interview schedule, the pertinent column answer number is sixty-three.

CHAPTER II

RESEARCH DESIGN

Ex Post Facto Design Limitations

The limitations of the basic research design used in this thesis have been previously described.[1] A most important limitation is the lack of control over contaminating variables. Although some attempt is made to hold certain factors constant when comparing space with teaching methods, many factors were not controlled in this manner. Furthermore, some alternative interpretations could never be ruled out by ex post facto techniques. Without randomization of teachers among various facilities no causal inferences are justified.[2] Nevertheless, with certain relations being predicted prior to the survey, it would seem that causation may be plausible following the discovery of supportive associations.

Sampling and Nomination Procedures

This study involved schools from five Northeastern States:

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[1] Supra, pp. 15-17.

[2] Randomization avoids the possibility that teachers had selected facilities which appealed to them. More sophisticated designs -- e.g., rotating teachers among facilities -- could also be done if a few years were taken for the research. It may be that only certain types of school systems would ever permit randomization -- a factor which is possibly more serious than the lack of control in the present study.

New Jersey, New York, Connecticut, Massachusetts, and New Hampshire. Generalization to other sections of the country may not be legitimate since this region might have peculiar factors influencing teaching style and student attitudes. The five states allowed convenient travel and yet gave a wide diversity of conditions. Rural, suburban, and urban schools were studied. The states often provided similar communities with various degrees of state aid and supervision. The nomination procedure involved several education officials from each state. Soliciting nominations from several states minimized the influence of any particular bias held by one state department's personnel.

The purpose of this study has influenced the choice of sampling technique. This research is intended to provide information for architects and educational consultants who wish to modify their practices to design better schools. It was felt that judgments concerning future construction of school science facilities should be based on experience with schools that have been recognized as doing commendable work, considering their types of communities and students.[1] Therefore, this study reflects associations between good science teaching and architectural characteristics. It would seem foolish to base recommendations for science facility construction on severely overcrowded classrooms, regular first courses in science subjects taught without laboratory, teaching under provisional certification, teaching under budgets that prohibit regionally appropriate salaries, or instruction done by lethargic teachers. In summary, the study wishes to gain understanding of architectural influences under optimal conditions.

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[1] Although the intention was to study schools having exemplary science departments, nominations could have been based on overall curriculum standards. Such selection is justifiable since science should not be stressed to the detriment of other subjects.

The testing of hypotheses under such conditions increased the task of the investigator -- the rejection of the null hypotheses. It would have been relatively easy to associate lecture type of teaching with poor laboratory conditions and indifferent teachers who may not have had training in science. Such teachers have practically no choice but to lecture. The hardest test of the general hypothesis occurs when a teacher apparently does have the option of teaching by any methods..

Since 1958 our nation has spent large amounts of money in science instruction. The design of science facilities changed to reflect more active student participation. It was felt that design studies should not investigate obvious impediments of old architecture, but should investigate current architectural practices. For this reason, visits were planned to only those schools which had opened since January 1960 or had undergone major renovation since that date.

Another reason why schools were not selected at random still remains. The reason is found in being prepared to answer the following objection to the study.

> Your study involved teachers who were influenced by facilities, but my school system hires only the best teachers. My teachers will improvise where others would give up. Facilities do not influence teachers who are trained properly and who have enthusiasm.

The design of the sampling technique would allow the following reply to the objection:

> It would be hard to find better teachers than were included in our survey. The Project interviewed science teachers who, as a group, one would expect to find in the best science departments of the region. The Project did not interview all of the region's good science teachers, by any means. However, the nomination procedure greatly limited the number of poor science teachers interviewed. Furthermore, the selection of schools to be visited was based on decisions made by administrative personnel, probably using the same rough evaluative techniques that superintendents use when hiring personnel.

The judgment of what is considered a good science department or a good science teacher is very subjective. Since most teachers are hired by administrative personnel, it was felt that such personnel should nominate the schools. Although the criteria are vague, it would appear that out of the many good schools in a state, approximately ten schools could be nominated so that the Project would avoid mediocre teachers and departments.

With the aid of each state's education department, schools were selected from among the most exemplary high schools in that state. The letter requesting nominations gave the following guidelines for selection.

> Since this study may be used to guide the design of future architectural spaces, and since the findings should lead to improved educational specifications, we are examining only the more successful examples of school design in which we hope to find a variety of teaching methods and facilities. It would be advantageous for us to investigate a variety of urban, suburban, and rural schools as long as each high school may serve as an example for some others to follow.

Other than being exemplary high schools in educational reputation, as well as architectural reputation, the nominated schools were supposed to meet two other criteria:

1) They should be three or four year public high schools.

2) The building must have been built since 1960 or the science facilities in older buildings must have undergone major renovation since 1960.

In some sparsely settled areas, six year high schools were nominated and were included in the study. Although no junior high schools were nominated, some were visited because they fed a nominated three year senior high school. Criteria for what an exemplary school should be were left up to the state department's staff, except as restricted above.

All five states contacted replied with nominations, usually saying they could supply many more names. The states were selected to give a wide, but a regional range of communities, resources, and state control. The states included in the survey are listed in Table One with the number of high schools each nominated.

All schools were included in the sample, although there were fourteen more than anticipated. However, as will be discussed later, five of these schools were not visited -- one from New Jersey, two from New York, and two from Massachusetts. Only one of these resulted from a refusal to participate.[1]

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[1] Because the investigator would not reveal the sources of nominations, the Superintendent of Norwich, New York declined to participate.

TABLE 1

NUMBER OF SCHOOLS NOMINATED BY EACH STATE

State	Number of Schools
New Hampshire	12
Massachusetts	13
Connecticut	12
New York	15
New Jersey	12
Total schools nominated	64
Total schools visited	59

Interview Technique

Reasons for the Method

Persons involved

It was not difficult to devise a method for measuring the independent variables. This information could be obtained by questionnaire or by direct visitation, the latter possibly giving more validity. Teachers may not report available facilities because they have not used them, or teachers may not know that facilities exist.[1]

The choice of a method for measuring the dependent variable, instructional method, was more difficult.

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[1] If a teacher did not feel that he could gain entrance to the school or if he did not know a television was available for his use, his negative answers were considered valid even though the burglar alarm could be deactivated or a television was hidden in the audio-visual stockroom. However, if the teacher denied the existence of an obvious facility such as a pond, marsh or woods, the negative answer was revised to indicate the presence of this facility.

Oddly enough, asking teachers about their teaching methods is not the usual way to determine what is happening in a classroom.[1] In fact, several teachers asked why I did not obtain my answers from watching them. Certainly, observation could have been one alternative to the interview schedule. There are, however, several disadvantages to the observational technique. First, it takes much more time to gain any information by watching the slow development of a lesson. Second, few mechanical techniques have been perfected that reveal significant but subtle nuances in teaching techniques. Observers still must use intuition and skillful insight when determining what a teacher is trying to do.[2] Third, even given well trained observers, observations would have to occur for many periods throughout the school year in order to get relevant data. These visits ought not to be random, unless they occurred as frequently as two per week per class. One must realize that teaching methods are not randomly scattered throughout the year; some blocks of lab are followed by a long period of no lab at all. The closest observer who could do such constant observation is the science department chairman (if he has no teaching load and few administrative duties). Nevertheless, he is not trained in a standard fashion for carrying out such observations. The chairman has much to lose and little to gain in revealing his personal evaluation of his teachers to a stranger.[1] No matter who does the observing, such a method would be impractical -- possibly only valid after exhaustive training and testing of an observation staff.

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[1] The reluctance to rely on teachers for valid answers probably stems from some supervisory practices where certain answers could benefit a teacher.

[2] Successful or not, what a teacher attempts to do with a class is the dependent variable. If, after a trying period practicing a dry, inquiry lab with a group of unresponsive students, a teacher gives the answer to the problem -- the class is still termed a dry inquiry lab for this research. It is felt that teacher training and experience might modify such an approach so that it becomes successful. The important factor is that the teacher is trying such a method as his modal technique.

Another alternative method could involve students as the respondent to an instrument or as the observer. Questions could be worded possibly to avoid concepts which students did not comprehend, but this does not guarantee valid perception of what was happening in class. Interviews could probe when misunderstanding was evident, but to interview a large number of students for one teacher poses tremendous time problems. Furthermore, administrators probably would frown on such a disturbing survey taking place in their schools.

It was decided that teachers would have little to lose if they cooperated in the survey; and that if they could be convinced of this, teachers would be the best informants on their own behavior and their intents.[2] It remained to decide how one could best elicit cooperation from teachers.

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[1] In two cases, teachers were excluded from the survey because their answers were obviously fictitious. These suspicions were confirmed by the department chairman. One teacher asked the chairman what he should say and proceeded to reply as if he were doing experiments constantly, where only window sills and tablet arm chairs provided working space. Another teacher claimed he was teaching a course not assigned to him.

[2] To some extent, immediate intentions were considered behavior;

Mode of data gathering

Teachers could have been asked about their teaching methods either by questionnaire or interview. A mailed questionnaire was not chosen, even though such a technique would have enabled the sample to be larger and have national distribution. The interview was chosen for three major reasons.

First, with many questionnaires burdening teachers from other research projects, a low return rate could be anticipated with dubious interpretations of data gathered. On the other hand, most teachers would willingly talk with someone who spent time and money traveling to see them.[1]

Second, questions may be interpreted in a mistaken manner. The interviewer, while remaining unbiased, could explain the intention of the question or probe answers if apparent inconsistencies occur. If a teacher's situation is peculiar, the interviewer is in an excellent position to decide if a non-relevant blank answer would be appropriate.

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if an inquiry lesson was poorly handled by the teacher, a student or observer might think that it was just an ignorant teacher not knowing what he was supposed to teach. Students may not respond to inquiry techniques and may cause the teacher to eventually change his technique. In this case, it was the original teaching strategy for every class period which would be considered valid for determining modal teaching method.

[1] A nickel is the expense a teacher sees connected with the mailing of a questionnaire. Interviewing on a tight schedule shows effort is being expended -- often missing lunch or starting as early as 7:30 A.M. In some cases, it cost fifteen dollars to interview each teacher in an isolated school because of air fare, hotel expenses and ground transportation.

Third, it was anticipated that much could be gained from anecdotal remarks. Such remarks could be more meaningful if gathered during a discussion, rather than appearing as short remarks on a mailed form. Anecdotal remarks certainly proved to yield important suggestions for future design, but formal analysis or even compilation of these remarks will have to come after the writing of this thesis.[1]

The Interview Itself

The 494 structured interviews[2] were conducted in semi-conversational style and individually with all but four teachers. The environment of the interview was dependent on available rooms in the various schools, but most administrators tried to provide private facilities. Less than thirty teachers were necessarily interviewed in rooms with others; some were interviewed in study halls or laboratory periods; many were interviewed on their own suggestion over coffee in the teachers' lounge. None of these situations put any noticeable pressure on the teacher to answer in any one manner.

Four teachers were interviewed in pairs; the department heads had picked good friends for these pairs. To ease this situation, made necessary by scheduling problems, the interviewer chose different levels of students with which each teacher concerned himself. Since each teacher would be talking about a different type of class, the teachers would not need to compete for prestige by giving biased answers.

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[1] Significant trends and errors in ventilation were detected through anecdotal remarks. The relationships of vocational agricultural facilities and rural environments with science instruction were also explored. Trends in science project work were also detected. Equipment installation often revealed gross misunderstandings on the part of manufacturers. Administrative procedures also were noted where they might prevent certain modes of teaching.

[2] A copy appears in Appendix A.

Each interview lasted twenty to thirty minutes. A tour of the facilities usually followed the interviews; sometimes a brief walk through the facilities preceded the interviews. Most teachers were interviewed during their free "planning" periods; never was a teacher kept after school unless he usually stayed after school. Up to twelve teachers would be interviewed in one day. Visits to schools were limited to one day if all teachers of tenth through twelfth grade subjects and teachers of ninth grade biology could be interviewed.[1] Some schools were small enough that earth science teachers, regardless of grade, could be interviewed. In some cases, general science teachers were interviewed to avoid slighting these teachers when everyone else was involved in the study.

Questions concerning non-spatial and spatial independent variables were asked prior to questions regarding teaching methods.[2] This procedure, along with a small introduction explaining the purposes of the research, put the teacher at ease before he was asked about teaching methods. Anecdotal remarks were recorded during interviews as well as after school. Often department chairmen and some teachers would stay a few hours discussing design and curricular problems. Although some researchers would feel that such intercourse is not legitimate for interview studies, this period of discussion was thought proper since it returned the favor granted the Project by the administration. In no way did these discussions influence answers to the interviews which had occurred previously that day. When in conference with principals, the interviewer was careful not to betray confidences assumed by the teachers interviewed.

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[1] Interviews at Darien, Connecticut were not completed because of limitations in time. Teachers of physics, advanced courses and one biology course were intervewed.

[2] Only with two teachers was the order reversed in order to ask questions not answerable through observation. This was done when interviewing was behind schedule and teachers would not be available at another time.

Analytical Procedures

The results of the statistical analysis will be given in Chapter Four. The general procedure for that analysis will be discussed in this section.

Analyses were mainly computed by International Business Machine 7090/94 programs operating under the standard Fortran Monitoring System. The programs are explained in manuals for the Data-Text System[1] and The Multivariate Statistical Analyser.[2] The latter program, except for its INCOMPLETE R routine, proved too cumbersome to use except in preliminary analyses.[1] One of the main advantages of the Data-Text System was that each variable was analyzed only on the basis of those teachers of schools supplying information. Blank answers signifying irrelevancy or non-availability of information were ignored; this gave rise . to frequent changes in the population size. Another advantage of Data-Text was that variables could be created easily by redefining old data variables. This was especially helpful in creating ordinal or nominal data from interval scales of wide range.

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[1] Arthur S. Couch, Data-Text System: Preliminary Manual (Cambridge, Massachusetts: Department of Social Relations, Harvard University, 1967).

[2] Kenneth J. Jones, The Multivariate Statistical Analyser (Cambridge, Massachusetts: By the author, 1964). This system is abbreviated "MSA."

Most analyses performed were non-parametric tests chosen prior to gathering the data. Appropriate changes in procedures were necessary to adapt for group sizes or unexpected distributions. Because some coefficients of association, such as tau C, may not be familiar to some readers, other tests may have been done with the data concurrently. Usually the scales of associational measures have the same end points, but have different intervals -- this fact makes it dangerous to judge the value of a tau C coefficient in comparison to other educational research giving contingency coefficients.

The data were screened first for significant associations between dependent variables (methods) and non-spatial independent variables. Although computer routines would calculate Pearsonian product-moment correlation coefficients and match their significance levels at either .01 or .05 probability, the tests often would actually be a point biserial correlation.[1] Those non-spatial variables having a relationship of .01 significance or better were selected as specifiers (nonparametric covariables) in subsequent analyses involving that specific dependent variable. In some cases, intuition or tetrachoric correlations provided leads to significant specifiers which had violated the assumptions of the Pearsonian product-moment correlation and had not given significant coefficients. The continued use of a specifier depended on its performance during the final analyses of crossbreaks[2] between spatial and dependent variables. Therefore, the fulfillment of all data assumptions involved in the selection procedures of non-spatial specifiers was not critical.

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[1] Most MSA routines would count blank fields as zeros. This would distort most statistics involved with the present study.

Following the determination of significant specifiers, these nonspatial variables (usually interval in nature) were divided logically into nominal and ordinal categories for use with contingency tables. The specifier never appears as a variable on any one contingency table, for the specifier states what condition a teacher must fulfill before that teacher's answer is placed in the table. The specifier establishes the conditions under which the analysis is being made. Non-spatial variables form the third through nth dimensions in a specified crossbreak table.

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[1] Although their tests of significance do differ, the correlational measures are identical. The tests of significance are so similar, that for preliminary screening of relevant non-spatial variables, computer results were used.

[2] Kerlinger, p. 625, gives a definition of this term, "A crossbreak is a numerical tabular presentation of data, usually in frequency or percentage form, in which variables are juxtaposed in order to study the relations between them." This refers mainly to Fisher exact test tables or chi-square tables in the immediate case.

The size of the interval in the nth dimension would determine the size of cell groups in the various contingency tables scattered along the nth dimension. Some crossbreaks may have several pertinent non-spatial variables. Small intervals in each one of these non-spatial variables would make group sizes too small for legitimate analysis. Yet, other crossbreaks may have only one pertinent specifier. This latter crossbreak could benefit from added ordinal information by having small intervals in the non-spatial variable. So it will be seen that the original data denoted in Appendix A by the value X(1...n) is often redefined into new variables, denoted by VAR(1...n').[1] For the purpose of maximizing cell size but retaining as many subdivisions as possible, a variety of scales for the variables has been made. Appendix B gives the recodings of the variables, including some not used in final analyses.

A serious objection can be raised to multiple subdivisions of interval ranges. If the subdivisions are not logical, spuriously high associational values may result. All variable subdivisions in this thesis have been made as follows: 1) with a priori reasons based on teaching experience; 2) by intuition prior to the survey; or 3) at accepted statistical points such as the mean, median, modes, extreme tails, or at 0.5 or 1.0 standard deviation. Each appropriate variation is tried as a specifier to see if cell sizes, significance levels, and associational values benefit from one specific breakdown. Furthermore, the more elaborate breakdown of one variable may yield higher associational values than dichotomous breakdown of two separate variables.

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[1] For example, the number of preparations per day (X-17) varies from one through five. This small interval scale is correlated with inquiring lab centered course work, rather than verifying work (X-55). X(17) is correlated also with a course being inquiry-oriented (but not possibly wet lab centered -- X-44). The latter item correlates with three other non-spatial variables, whereas X(55) has no other non-spatial correlates. With the same population, it is obvious that of the two variables, X(44) and X(55), X(44) is more sensitive to subdivisions of X(17). X(44) must have large group sizes for three remaining crossbreaks.

Each hypothesis is first tested with every variation of the independent spatial variable and the dependent variable without non-spatial specifications. Even if this does not show a significant correlation, various crossbreaks are tried next. Each non-spatial variable is added to the "unspecified" contingency table. From the associational values among various specified conditions for contingency analysis, the best values are taken. To these three dimensional crossbreaks is added a fourth variable (the second non-spatial variable). This selection continues until cell sizes drop too low for legitimate analysis. The specifiers are then presented as conditions under which architectural space becomes limiting. Actually, architectural space never becomes the one limiting condition since teaching method is not perfectly predictable from design characteristics.

Applications of Conclusions

Use of Formal Analysis

The formal analysis performed in this thesis has followed some statistical guide lines which may have limited the conclusions drawn from all the available data. This attempt at fulfilling the assumptions, involved with tests or experimental design, has allowed stronger conclusions to be made without undue reservations. The purpose of the formal analysis is to produce conclusions useful in four ways.

First, architects and others could use evidence, produced by this research, to support their requests for more complete educational specifications. The general hypothesis reflects the primary purpose of the research -- to establish that science facilities are associated with science teaching methods at the secondary school level.

With the rationale supplied, it is plausible that a causal connection underlies the significant associations found. Even with alternative interpretations, there still remains an association.[1] Essentially, the establishment of a significant association allows an administrator to predict what teachers will be doing several years hence in a building which may last decades. Low associational values reflect that other factors also must be considered, but that these other factors need not be known to exercise one's best judgement in the sphere of architectural design. To delay exercising knowledge in the architectural sphere until complete understanding is gained may well result in creating rather permanent impediments to teaching.[1] If architectural characteristics foster certain types of teaching, administrators (and curricular projects) might spend more time planning facilities in accordance with the model[2] for drafting educational specifications.

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[1] The term, "association," is used since "correlation" is usually reserved for parametric statistical analyses. Most analyses in this thesis are non-parametric.

Second, science staff members in schools could use the results of this survey to show reasons for their requests. During the drafting of educational specifications, opinions of science staff members often are not appreciated. Some of these opinions may have to be revised in light of a larger sampling of experience; other opinions may find support in this survey. This research should aid in the translation of educational specifications to architectural design. This translation, although primarily the architect's responsibility, should be aided by suggestions from persons versed in science.

Third, architects and educational consultants can base some decisions on at least the ex post facto research done here, rather than on pure opinion. One important decision, which may be aided by the current research, concerns the relationship of laboratory space and the classroom.

The statistical nature of these findings overlooks the exceptional staff. For instance, one cannot say with absolute surety that a greenhouse will not be used for fostering experimental work in biology -- even though the presence of a greenhouse is not highly associated with the experimental use of plants. Two schools, those in Wilton, Connecticut and Keene, New Hampshire, stand out as examples where legitimate use is made of greenhouses. It would be unwise to weigh conclusions of this thesis as the only information upon which to base architectural decisions. In this specific case, Wilton's programs would be hampered and teacher morale lowered if future additions did not allow expansion of the greenhouse. Nevertheless, the administrator must realize that these highly motivated teachers may have successors who will not use this facility. One purpose of this research is to alert administrators of possible disuse of some facilities and to discover circumstances under which use may or may not be encouraged.

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[1] The flexibility included in many designs was an attempt to skirt this difficulty, however flexibility may necessitate impediments not present in more specific design.

[2] See Figure One, supra, p. 8.

The previous example leads to the fourth use of the research -- working toward better utilization of facilities. If certain facilities are not being used as intended, substitutes[1] or improvements for the unused facilities might be designed. The need for acquaintance with utilizing some facilities may become apparent. Teacher training might include specific instruction in technological details connected with unused facilities.[2]

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[1] With greenhouses, large, artificial growth chambers may act as substitutes.

[2] Care must be exercised in the case of greenhouse training for teachers. This instruction may result in non-experimental use of the facility.

Use of Anecdotal Remarks

Anecdotal remarks are not subject to the same safeguards as are conclusions derived from formal analysis. One objectionable feature is that anecdotal remarks rarely are elicited from the entire sample. Teachers at the start of a survey volunteer such remarks; then the interviewer begins to question respondents on the same topic. The interview schedule in Appendix A gives examples of anecdotal remarks mentioned so frequently during the trial interviews that the information was coded on the questionnaire. Anecdotal remarks will eventually be analyzed in conjunction with each specific hypothesis and probably will be published or circulated to participants as small memoranda. Two such topics will be concerned with ventilation and scheduling arrangements.[1]

Although anecdotal remarks lack statistical vigor, they have strong rational backing and are the result of a few hundred teachers suggesting improvements for design of their facilities. At present, there is often no better way to make architectural decisions than to base one's choice on such wide and reasonable experience.

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[1] Anecdotal remarks, now on the interview records, indicate that some administrative procedures can impede the use of certain facilities. One clear example involves scheduling of classes in classroom-laboratory situations. If the same teacher and students do not meet together for both class and lab, the usual effect seems to be non-inquiry teaching. The coordination of discussion and lab, made possible by the combined classroom-laboratory design, is not usually present when another teacher is scheduled as lab instructor or when students are mixed among different teachers' classes for double lab periods. With one chemistry class, a sixth period during the week was given "back to back" with a discussion period. However, the same students were not scheduled for both halves of the double period! It is evident that some administrative practices act in a way which is equivalent to having radically different types of facilities. Such uncontrolled factors will tend to reduce the associational value found between architectural characteristics and methods of teaching.

Since the interviewer sifts anecdotal remarks before recording, the value of recommendations founded on anecdotal remarks rests purely on the investigator's ability and experience in the science facility field. Until research, even ex post facto research, investigates anecdotal recommendations, the reporting of collective opinion is the next best type of knowledge to be publicized.

CHAPTER III

REPORT ON THE INTERVIEW PHASE

Following the development of a suitable research design, a preliminary edition of the interview schedule was developed. Some preliminary discussion on the acceptability of the research was done with Mr. John Packard of the Massachusetts Department of Education. On January 23, 1967, requests for nominations of schools were sent to the State Departments of Education.[1] While waiting for replies, the investigator began the trial survey on January 30, 1967.

Trial Survey

The trial survey proved to be of benefit in establishing smooth administrative procedures for the scheduling of interviews as well as a period in which to revise the interview instrument. During the trial period, permission was being obtained for visiting the first few schools in the final interview phase. It appeared that school personnel would be very cooperative when the visits began in earnest, February 28, 1967.

Because inclement weather cancelled several school operations during the month of February, only three high schools in the vicinity of

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[1] The states were New Jersey, New York, Connecticut, Massachusetts, and New Hampshire. The reasons for selecting these states are given supra, pp. 43-44.

Boston were visited, giving a total trial population of nineteen teachers.[1] The schools visited were 1) Mansfield High School, Mansfield, Massachusetts; 2) Phillips Academy, Andover, Massachusetts; 3) North Reading Senior High School, North Reading, Massachusetts.

Close attention was given to the performance of the revised interview during the first three visits to schools in the final survey population. Although no major changes were made, allowance for changes was planned if this second group of schools revealed any inadequancy in the instrument. These three semi-trial schools were 1) Natick High School, Natick, Massachusetts; 2) Salem High School, Salem, New Hampshire; 3) Timberlane Regional High School (modularly scheduled), Plaistow, New Hampshire.[2]

Arranging Interviews

Acceptances and Refusals for Participation

The state departments of education nominated schools to be approached for inclusion in the study. The first task was to identify the superintendent in charge of each high school and to request permission for conducting the research. Various directories were used from regional associations, professional associations, and the Office of Education. In two cases, superintendents did not reply. One superintendent was never reached because the wrong one was contacted and he did not reply until too late in the survey.[1] The other superintendent did not reply to two letters; possibly, they never reached the proper individual.[2] Since there was an oversupply of schools to visit during the last month of interviewing, the pursuit of these contacts would not have changed the final interview sample. Nevertheless, the directories available for identifying superintendents left much to be desired. It was a major task to locate information concerning current superintendents. However logical it may have seemed to ask the State Departments of Education for this information, the investigator did not wish to burden others with chores that he could do.

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[1] Other extenuating circumstances reduced the trial school sample, namely school vacations and an arm injury which prevented the investigator's driving.

[2] This effectively raised the trial population to forty-one teachers, thirty-three of whom were from schools nominated by state department personnel.

Letters sent to the superintendents requested permission to approach the principals for approval to visit the high school and interview teachers. Some information pertaining to the entire school system was also obtained from the superintendent's office. Upon receiving the superintendent's permission, contact was made with the principal named in the reply letter. The principal's permission letter supplied information including the name of the science coordinator or department chairman who would be contacted by the Project for final arrangements. The letter to the department chairman gave him enough freedom so that he could essentially refuse participation by postponing the visitation date. About fifteen variations of form letters were sent to superintendents, principals, and department chairmen. Variations were necessary to personalize the letters so that some knowledge of their school was indicated.[1] Example copies of each kind of letter are included in Appendix C. If arrangements were made by phone, entirely different confirmation letters were sent. Appointments were made sufficiently in advance to allow department chairmen to alert teachers. A few schools received short notice because of poor mail handling, but this was infrequent.

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[1] The school missed, because of this error on the investigator's part, was the Whitman-Hanson Regional High School, Whitman, Mass.

[2] The school missed in this situation was New Brunswick Senior High School, New Brunswick, New Jersey.

Sequence of Visitations

Table Two indicates the schools nominated along with the schedule and number of teachers interviewed from that school or feeder junior high schools. The order of visitation may have some importance for two reasons:

1) The interviewer may have unconsciously changed his style after a few hundred interviews. The speed at which questions were stated quickened as they became more familiar. Boredom was not a factor,

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[1] For instance, if the superintendent had indicated no ninth grade biology was being taught, principals were not asked for the junior high school principal's name and address. If the principal indicated that there were only a few teachers in the science department, the chairman was requested to include all, or at least earth science, teachers in the interview appointment schedule. All letters tried to convey the impression that each school was respected as a distinct school and not a computer code number. All letters were individually typed.

except in one school near the end of the survey. In fact, the traveling was a stimulating experience and teachers always seemed to present new opportunities to learn more about administration of science staffs. A more natural conversational approach was cultivated during the course of the survey, but all questions were asked verbatim as on the interview schedule. Sometimes these questions were prefaced with, "Did you say that...?" or "It's my impression that you..." Such remarks made the interview less of a trial for the teacher and gained necessary rapport.

2) Teachers may have had better knowledge of the current year's teaching style if all the interviews had been in May or June. Nothing could be done to prevent this, unless a large staff had been trained for an intensive, short-lived interview period.

No analysis was done to detect correlations with date of interview, but no predictions could be made on logical grounds that certain types of facilities were visited late or early in the survey. It is true that covariance techniques might have been used to allow for changes in response with time, but such methods could not be utilized with many of the analyses made here. Using time as a crossbreak would have reduced sample size before any relations could have been studied.

In general, visits were spread throughout the survey period in geographical distribution and types of communities. The first schools to reply usually were interviewed before others, but this was not always

TABLE 2

NOMINATED SCHOOLS AND VISITATION RECORD

Name of School ...High School[a]	Location	Date Visited (1967)[b]	Number of Teachers[c]
Plattsburg Senior	Plattsburg, N.Y.	March 18	4
Scarsdale Senior	Scarsdale, N.Y.	April 17	11
Elmira Free Academy	Elmira, N.Y.	May 1	10
Ithaca Senior	Ithaca, N.Y.	May 2	11
J. F. Kennedy Senior	Plainview, N.Y.	May 3	10
Cold Spring Harbor	Cold Spring Harbor, N.Y.	May 4	5
Northport Senior	Northport, N.Y.	May 5	13
Niskayuna	Niskayuna, N.Y.	May 11	10
Newburgh Free Academy	Newburgh, N.Y.	May 22-23	18
Williamsville Senior	Williamsville, N.Y.	May 24-25	10
Hamburg Senior	Hamburg, N.Y.	May 25-26	10
Pittsford	Pittsford, N.Y.	June 1	9
Pelham	Pelham, N.Y.	June 5	8
Liverpool	Liverpool, N.Y.	d	..
Norwich	Norwich, N.Y.	e	..
Natick	Natick, Mass.	Feb. 28, March 6	12
Tantasqua	Sturbridge, Mass.	March 20	6
Minnechaug Regional	Wilbraham, Mass.	March 23	7
Hingham	Hingham, Mass.	April 3 and 5	10
Lee	Lee, Mass.	May 9	6
Lincoln-Sudbury Regional	Sudbury, Mass.	May 12	10
Wayland	Wayland, Mass.	May 29	9

TABLE 2--Continued.

Name of School ...High School[a]	Location	Date Visited (1967)[b]	Number of Teachers[c]
Ayer Junior-Senior	Ayer, Mass.	May 31	6
Plymouth-Carver Regional	Plymouth, Mass.	June 2	9
Needham	Needham, Mass.	June 13	12
Sharon	Sharon, Mass.	June 14	3
Masconomet Regional	Topsfield, Mass.	f	..
Whitman-Hanson Regional	Whitman, Mass.	g	..
Salem	Salem, N.H.	March 1	7
Timberlane Regional	Plaistow, N.H.	March 3	6
Hollis	Hollis, N.H.	March 15	2
Manchester Memorial	Manchester, N.H.	March 27	12
Lebanon	Lebanon, N.H.	March 28	4
Newfound Memorial	Bristol, N.H.	March 29	2
Mascoma Regional	West Canaan, N.H.	March 29	3
Keene	Keene, N.H.	March 30	7
Monadnock Regional	Swanzey Center, N.H.	March 31	5
Milford Junior-Senior	Milford, N.H.	April 4	7
Lin-Wood	Lincoln, N.H.	June 15	3
Pittsfield	Pittsfield, N.H.	June 15	2
Hartford Public	Hartford, Conn.	March 8-9	14
Richard C. Lee	New Haven, Conn.	March 21	6
Bristol Eastern	Bristol, Conn.	April 10	10
Staples Senior	Westport, Conn.	April 11-12, June 7	17
Suffield Senior	Suffield, Conn.	April 13	5

TABLE 2--Continued.

Name of School ...High School[a]	Location	Date Visited (1967)[b]	Number of Teachers[c]
Watertown	Watertown, Conn.	April 14	8
Trumbull	Trumbull, Conn.	April 20-21	12
Housatonic Valley Regional	Falls Village, Conn.	May 10	5
Brien McMahon	Norwalk, Conn.	June 6	8
Darien	Darien, Conn.	June 7	5
Wilton	Wilton, Conn.	June 8	6
Torrington	Torrington, Conn.	June 9	9
Barringer	Newark, N.J.	April 6-7	15
Watchung Hills Regional	Plainfield, N.J.	April 24	8
Bridgewater-Raritan...West	Raritan, N.J.	April 25	13
Fair Haven-Rumson Regional	Rumson, N.J.	April 26	6
Monmouth Regional	New Shrewsbury, N.J.	April 27	10
West Morris (Regional)	Chester, N.J.	April 28	10
Westfield Senior	Westfield, N.J.	May 15	10
Cherry Hill...West	Cherry Hill, N.J.	May 16-17	16
North Hunterdon Regional	Annandale, N.J.	May 18	7
Northern Highlands Regional	Allendale, N.J.	May 19	7
Oakcrest	Mays Landing, N.J.	June 12	10
New Brunswick Senior	New Brunswick, N.J.	g	..

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[a] Add the words "High School" to the end of each name or where "..." is noted. The Elmira

TABLE 2--Continued

Name of School ...High School[a]	Location	Date Visited (1967)[b]	Number of Teachers[c]

Free Academy and Newburgh Free Academy are not called High Schools. Total number of schools nominated was 64.

[b] This does not include return visits for absentees; but it does include visits to junior high schools, if applicable. Total number of schools visited was 59.

[c] This may include biology teachers from feeder junior high schools. Total number of teachers interviewed was 496.

[d] This school was not visited because a fire had destroyed its science facilities about the time occupancy took place. The teaching situation for the entire year was not normal. Visitation was welcomed, but time did not allow inclusion of this school.

[e] Superintendent refused participation.

[f] This school was not visited because it was older than the arbitrary age set for the study. Visitation was welcomed, but time did not allow inclusion of this school.

[g] Superintendent could not be reached.

the situation.[1] To avoid extreme travel expense, visits to some schools which replied early were delayed until one trip could include several schools in the region.

Completion of Visits and Interviews

Interviews began on February 28, 1967 and ended June 20, 1967 with two interviews of absentees. The details for interview appointments were left up to the department chairman or principal. Not all schools gave teachers free periods; but even in these schools, the effort extended, in relieving teachers of duties while being interviewed, resulted in a smooth operation at almost all of the fifty-nine schools.

Absentees

Absenteeism could have been a serious factor, but very few teachers did not report for duty on the interview days. This acceptance of the interview may be attributed to three factors. First, teachers were complimented by having their department nominated as an exemplary science department. They knew this before the investigator came. Second, facilities are a deep concern to most teachers and they wanted to voice their opinions. Third, department chairmen could choose the date for interviews. A few postponed the interview to avoid a Jewish Holiday or field trips.

If absentees are defined as those persons on the senior high teaching staff not interviewed but qualifying for an interview, there were only twelve such teachers in the sample.[1] All but five of these absentees were eventually interviewed during other brief visits when the investigator was in the vicinity of the school. Of these five, two wanted very much to be interviewed but were seriously ill. The third was a department head who doubted that such a young interviewer could find out how he taught. This department head thwarted the interview with questions and anecdotal remarks so that the interview was not completed. The other two were teachers who missed their appointments and could not be interviewed because the investigator was not returning to the area. Therefore, it appears that only three teachers, from three different schools, could have had a common factor which was not measured. The effect of these teachers among a sample number of 496 would be insignificant.

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[1] Schools nominated by New Hampshire usually were visited early since those nominations and permissions were received with dispatch.

Junior High Visits Incomplete

As was suspected in the trial survey period, visits to junior high schools were very time-consuming. For this reason, many junior high schools had to be dropped from the survey. Schools were eliminated primarily when coordination through the high school was non-existent, thereby not allowing a schedule to be made for the same day of the visit to the high school. Junior high schools were most often interviewed when:

1) the senior high school was so large that it required two days

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[1] Not all absentees reported sick, three were on field trips and two missed their scheduled appointments (but were willing to be interviewed).

to complete the visit.

or 2) the junior high school was located near Boston.

Therefore distant suburban schools were the main type of junior high schools dropped from the survey sample.[1] However, many such junior high schools were included in the survey. Suburban and city junior high schools included in the survey were from such places in New York State as Elmira, Hamburg, Newburgh, Northport, Williamsville; in Massachusetts as Hingham, Natick; and Westport in Connecticut.

Coding and Card Punching for Analysis

After the gathering of all data on the interview forms, information was entered in the marginal spaces of the form. This transfer of answers to the margins facilitated key punching and allowed a check on the correct coding of such answers as X(23) and X(25).[2] Before marginal answers were entered for X(6), X(8), and X(59), additional computations were made from raw data supplied by the teachers' answers.

Code Adjustments

After the raw data had been gathered, it was apparent that a few of the categories did not reflect the natural range nor the natural categories of the answers. Adjustments were made, as described in this section, to reflect natural categories or to foster accuracy in key punching with a minimum of distortion to the data.

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[1] Small rural high schools rarely had any junior high schools feeding them.

[2] Data variable codes, e.g. X(23), can be understood by question references given in Appendix A.

Periods per week, X(15)-X(16)

Some teachers had an alternating schedule of two double periods one week and three double periods the next week. In weeks which had two double periods, there would be three single periods; in weeks which had three double periods, there would be two single periods. Such a schedule averages two and a half single and double periods per week.

A complication occurred in coding because only one column was allotted for each answer.[1] To relabel column numbers throughout the interview schedule would have been laborious and time-consuming for 496 forms. Card punching would have been subject to many mistakes if valid column numbers were not present on every interview form. Therefore, it was decided to round all two and a half period answers to the type of schedule which usually is used by teachers having the alternating schedule. Two and a half period schedules were classified as two double periods and three single periods per week. This rounding may have reduced the associational values to some extent.

Predominant organism, X(36)

By the end of the interview phase, it was evident that the question for variable X(36) was not worded in the most useful manner. This question was answered affirmatively by biology teachers, in the main; but a few earth science and chemistry teachers, using living organisms, also answered. Teachers answering that they most often used microorganisms were six times greater than those using plants or animals. For a more informative question, answers were changed if they indicated ties between microorganisms and plants or animals. These new answers would indicate the plant or animal choice only. It was this revised keying which yielded the answer ratio cited above. Most of these teachers who indicated use of microorganisms did not do elaborate experiments or culturing. Information was being sought on the use of plant and animal facilities, and even with revised keying, less than sixty teachers yielded data to be analyzed.

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[1] Doubling of all answers might have been the solution to this problem; but some answers were five or six periods per week, which when doubled would have given a double digit number.

Cost of a lab period, X(8)

Once again, the range of answers exceeded the column allowance for answers. Actually only one school needed to have its teachers' answers adjusted, since it spent more than $9.99 per laboratory period.[1] The next highest school spent $8.95. In order not to create problems in key punching, a maximum of $9.99 was set, thus avoiding the need for a fourth column. As stated before, the addition of a fourth column would have resulted in more errors through punching of data in columns not labeled correctly on the interview schedule.

The high $9.99 value had almost the same effect as if it had been coded by its actual value. Most analyses were conducted by ordinal or nominal categories; these kinds of analyses would not be affected by this change in coding.

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[1] Actual cost per lab period was $11.29 for this school.

The dollar decimal occurs between column twenty-seven and twenty-eight. This cost is expressed to the nearest cent.

Size of sinks, X(39)

The interview questions were formulated without wide knowledge of exact equipment specifications. It later proved that sink manufacturers grouped their sinks in slightly different categories than the options for X(39). In order to have choices reflecting the actual classes of sinks, dimensions of fifteen by eighteen inches were the minimal qualifications for class four, and dimensions of nineteen by twenty-seven inches were considered the minimum for class five sinks. Extremely few sinks possessed qualifications of the original class five. Even with the revised standards, only 16 out of 226 teachers had sinks in class five.

Average departmental budget, X(6)

No alteration was actually done with this figure. Space limitations in columns made it necessary to round off to nearest tens of dollars. This usually resulted in dropping a zero.

Card Punching

Cards presenting the basic data to the computer were punched and verified by repunching on a verifier by the investigator. Such verification by the same key-puncher is not recommended usually. However, in this situation the chance of systematic error is slight since the investigator does not touch-type. The desire for accuracy was greater during card punching than would have occurred with hired key-punchers.

The verified deck of data cards was used to duplicate cards for use in computation. Duplicate cards were verified internally during duplication by machine. There exists no doubt, in the investigator's mind, about the accuracy of the data at the time the computational programs began the analysis. The original, verified data cards will be kept with the investigator for a reasonable length of time following the termination of the Facilities Research Project.

CHAPTER IV

ANALYSIS OF DATA

This chapter will present some statistical characteristics of the sample, then proceed to the analysis of each specific hypothesis, and finally discuss the general hypothesis.

Most of the analyses have been done with the Data-Text System.[1] Whenever the Data-Text System has not been used, the source of computational results will be noted. If possible, this will occur in parentheses directly after the statistic. If this procedure is not feasible, a footnote will be used. Three abbreviations will be used to indicate sources. MSA-R and MSA-D will refer to The Multivariate Statistical Analyser[2] routines, Incomplete R and Datasearcher respectively. Datasearcher treats blanks as zeros; because of this, four teachers were eliminated since they had numerous blanks in pertinent data fields. The program lists blanks so that no statistical procedure need be reported without knowing that a blank distorted the data.

Characteristics of the Sample

Statistical Definitions

A few specifications of the formulae or tests used by the programs are appropriate for unusually labeled statistics.

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[1] Couch -- supra, pp. 54-55.

[2] Jones -- supra, pp. 54-55.

Skewness

This statistic usually is computed by the Data-Text Statistics routine. Skewness, g_1, is calculated by means of the following formula:[1]

$$g_1 = \sum_{i=1}^{N} \left(\frac{X_i - \overline{X}}{s} \right)^3 \Big/ \; N$$

where s is the unbiased estimate of the standard deviation of the population using the sample obtained. N equals the number in the sample used for the distribution. The measure is an expression of the symmetry of a distribution. For perfectly symmetrical distributions, g_1 equals zero.

Kurtosis

This statistic usually is computed by the Data-Text Statistics routine. Using the same notation as with skewness, the routine calculates kurtosis, g_2, by means of the following formula:[2]

$$g_2 = \sum_{i=1}^{N} \left(\frac{X_i - \overline{X}}{s} \right)^4 \Big/ \; N-3$$

The measure is a discription of extent of variation from the central tendency in a distribution. Normal distributions have a kurtosis of zero.

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[1] Formula is given in Couch, p. 241.

[2] Formula is given in Couch, p. 241.

Normality test

The normality test reported in this "Characteristics of the Sample" section is computed by MSA Datasearcher (MSA-D). The calculation is the goodness of fit test provided by the Kolmogorov-Smirnov one-sample test.[1] The program divides the population into categories, one half standard deviation in size. The expected cell size calculation is based on the mean and sample number. The observed cell size is then compared to the expected cell size. The critical D values and observed D values are given with the alpha level of .01.

Schools

Since characteristics of schools appear on each teacher's data cards, the statistics presented as school-wide characteristics have a sample size of 496 rather than 59.[2] The mean and other statistics have an inherent weighting factor according to the number of teachers interviewed in connection with the high school.[3]

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[1] This is described in Sidney Siegel, Nonparametric Statistics for the Behavioral Sciences. (New York: McGraw Hill Book Co., Inc., 1956), pp. 47-52.

[2] Except for data variable X(59), teachers are free to answer the dependent variable questions in any way; this makes most samples the size of 496 before crossbreaks.

[3] Except for data variable X(59), non-spatial variable weightings would include junior high teachers interviewed within the same school system.

VAR(3), Average departmental budget

The average departmental budget[1] over the past few relevant years may indicate the wide range of financial situations visited. The following statistics describe the distribution:

1) N = 496
2) Mean = $6,609
3) Median = $4,750
4) Standard Deviation = $4,947
5) Range: $500-$21,500 (MSA-D)
6) Skewness = 1.208
7) Kurtosis = 0.441
8) The distribution is not normal at the 0.01 level. The D value equals 0.1850, the critical D being 0.0735 (MSA-D). The curve appears to be bimodal, 77 teachers were observed beyond +1.5 standard deviations in the second mode (MSA-D).

VAR(9), Budget per pupil

The science department budget[2] divided by the entire school's enrollment gives the following statistical distribution:

1) N = 496
2) Mean = $5.05 per pupil/year
3) Median = $3.76 per pupil/year

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[1] Infra, p. 176 describes the expenses germane to this budget.

[2] Supra, p. 83 explains VAR(3) which is the average departmental budget; see also infra, pp. 176, 192.

4) Standard deviation = $4.05

5) Range: $.80 - $21.50

6) The approximate decile maximum values based on cumulative percentages are as follows: 1/10 = $1.50; 2/10 = $2.00; 3/10 = $2.60; 4/10 = $3.50[1]; 5/10 = $3.80; 6/10 = $4.40; 7/10 = $5.50; 8/10 = $7.20; 9/10 = $9.10. Cumulative partial deciles in the extreme range are 9.5/10 = $11.30; 9.7/10 = $15.80.

7) Skewness = 2.053

8) Kurtosis = 4.828

9) A normality test is not available.

VAR(6), Cost per lab

This variable yields a bimodal distribution around the two and five dollar values. Table Three shows the bimodal nature in a transformed ordinal scale called VAR(7).[2] Below are given the statistics for the non-transformed data grouped by school.

1) N = 496

2) Mean = $2.70

3) Median = $1.52

4) Standard deviation = $1.87

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[1] Actually 47% of schools have $3.50 or less as their annual budget per pupil.

[2] See Appendix B for transformation code--infra, p. 203.

5) Range: $.55 - $9.99

6) Skewness = 1.888

7) Kurtosis = 3.845

8) The curve is not normal at the 0.01 level. The D value is 0.1545, the critical D value being 0.0735. (MSA-D)

TABLE 3

COST PER LABORATORY, VAR(7)

Category	$ .50- 1.25	$1.26- 1.75	$1.76- 2.25	$2.26- 2.75	$2.76- 9.99
Frequency of Teachers	72	66	133	64	161
Cumulative Percentage	14.52	27.82	54.64	67.54	100
Number of Schools[a]	7	10	13	7	21

[a] The number of schools is estimated from the number of groups having different costs. Two schools had identical costs, thus reducing the total number to fifty eight.

VAR(10), Total college entrants

The following statistics give a rough picture of the dominance of college-oriented policy in the schools. The figures represent the percentage of graduates entering college immediately after graduating from high school.

1) N = 483

2) Mean = 58.7%

3) Median = 60.0%

4) Standard deviation = 16.7%

5) Range: 30% - 98%

6) Skewness = 0.277

7) Kurtosis = -0.653

8) No test of normality is available.

VAR(16), School enrollment

The schools in this survey came from a diverse sampling of communities. The following statistics include the total enrollment for the school; the maximum number of grades included is six. These six year schools often had enrollments under 800.

1) N = 496

2) Mean = 1435 students

3) Median = 1407 students

4) Standard deviation = 593

5) Range: 226-2997

6) Skewness = 0.747

7) Kurtosis = 0.729

8) This curve is normal at the 0.01 level. The D value is 0.666, the critical D being 0.0735.[1] (MSA-D)

Table Four gives the distribution of schools and teachers for the transformed ordinal categories present in VAR(17).[2]

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[1] VAR(16) has as its values the number of students in the school of each teacher. In this case, normal distribution of school enrollment probably indicates a dominance of small schools since large schools have many teachers supplying data for VAR(16).

[2] See Appendix B for the transformation code.

TABLE 4

SCHOOL ENROLLMENT, VAR(17)

SIZE Min.	226	751	1001	1251	1501	2251
Max.	750	1000	1250	1500	2250	3000
Frequency of Sci. Teachers	54	75	82	87	153	45
Frequency of Schools	13	11	10	9	13	3
Averages Based on Ungrouped Data						
Sci. Teachers per School	4.2	6.8	8.2	9.7	11.8	15
Students per Sci. Teacher	119	138	139	145	149	184

VAR(21), Mean years in department

Total the number of years that a department's members have accumulated in their present high school. Then divide by the total number of teachers in the department. The resulting quotient is the mean number of years in the department. This variable may be termed "average years of departmental membership." The distribution of this variable is described below.

1) N = 496

2) Mean = 6.2 years

3) Median = 5 years

4) Standard deviation = 3.2

5) Range: 1-17

6) Approximate decile maximum values are 1/10 = 2 years; 2/10 = 3 years; 3/10 = 4 years; 5/10 = 5 years; 5.7/10 = 6 years; 7/10 = 7 years; 8/10 = 8 years; 9/10 = 10 years; 9.6/10 = 12 years.

7) Skewness = 1.204

8) Kurtosis = 1.889

9) The curve is not normal at the 0.01 level. The D value is 0.0833, the critical D value being 0.0735. (MSA-D)

VAR(65), Availability of a late bus

This anecdotal tabulation may reflect the desire of the sample communities to provide extra opportunity for late afternoon work. Late buses were available for students working on individual projects according to 333 teachers. No late bus was available for students of 119 teachers. Teachers living in metropolitan areas, with community bus service, were not asked this question.

Teachers

The following variables describe individual teachers, since answers could vary within a school.

VAR(1), Subject experience

Teachers as a group exhibited the following characteristics--regarding the number of years they had been teaching the subject, about which they provided answers throughout the interview.

1) N = 496

2) Mean = 7.593 years

3) Median = 5 years

4) Standard deviation = 7.141

5) Range: 1 (62 teachers) - 46 years

6) Skewness = 1.845

7) Kurtosis = 4.082

8) The curve is not normal at the 0.01 level. The D value is 0.1586, the critical D being 0.0735. (MSA-D)

In many cases, these years of experience were gained at schools other than the one now employing the teacher.

VAR(40), First course level

High ability students formed the classes taught by 85 teachers. Average college preparatory classes were taught by 265 teachers. Classes mainly comprised of terminal or possibly low ability students were taught by 78 teachers. These figures all pertain to the first course a student receives as an introduction to a specific science subject.

VAR(41), Second course level

The figures in this section refer only to courses capitalizing on one year's experience in the subject for the student. Twenty-three teachers taught advanced placement courses geared for passing the exam for college credit or exemption from freshman college courses. Sixteen teachers taught second courses to high ability students. Seventeen teachers opened their second courses to average college preparatory students.

VAR(42), Grade

Grade levels were sampled as indicated in Table Five.

TABLE 5

GRADE DISTRIBUTION OF TEACHER SITUATIONS PRODUCING DATA

Grade[a]	Number of Teachers
Ninth	89
Tenth	154
Eleventh	114
Twelfth	138

[a] Teachers may teach more than one grade in the course supplying data. The predominant grade was used as an answer. Teachers may also teach courses in different grades; only one course was chosen for the interview.

VAR(43), Course subject

Although teachers may have taught more than one course, their responses were limited to one course in order not to contaminate the data with correlated answers on any one variable. Therefore, all tests applied to the data are based upon independent answers. The teacher distribution for each subject is given in Table Six.

VAR(47), Laboratory-classroom relationship

This distribution hindered analysis of a major specific hypothesis. Only 80 teachers had separate laboratories, whereas 384 teachers had combination classroom-laboratories.

TABLE 6

TEACHER-SUBJECT FREQUENCY

Subject	Number of Teachers Responding
Earth Science	50
General Science	10
Physical Science	18
Biology	205
Chemistry	119
Physics	76
Integrated Science	10
Anatomy and Physiology	7
Other	1

VAR(50), Number of students in the laboratory

The average number of students in a laboratory may be indicative of overcrowding. Nowhere did the investigator find evidence of the supposed tendency toward very large laboratories. The distribution of laboratory size is given below.

1) N = 495

2) Mean = 21 students

3) Median = 22 students

4) Standard deviation = 5.7

5) Range: 3-35

6) Skewness = -0.445

7) Kurtosis = -0.110

8) A test of normality is not available.

VAR(56), Number accommodated in individual lab space

The following statistics describe the general availability of individual project space.

1) N = 495
2) Mean = 5 students
3) Median = 4 students
4) Standard deviation = 7.7
5) Range: 0-99 (9th decile = 12; 99th percentile = 30)
6) Skewness = 5.173
7) Kurtosis = 48.919
8) No test of normality is available.

VAR(63), Teacher has own classroom-laboratory

Teachers having their own classroom-laboratory numbered 131, whereas 253 shared their rooms.

X(10), Number of years in the system

This variable was especially tallied for this section; it was not used in analyses as a variable. The following statistics may help to describe the sample by indicating the number of years each teacher has been in his present school system.

1) N = 496
2) Mean = 6.153
3) Median = 4
4) Standard deviation = 6.229
5) Skewness = 2.174

6) Kurtosis = 5.841

7) The distribution is not normal at the 0.01 level. The D value is 0.1586, the critical D value being 0.0735. (MSA-D)

Dependent Variable Distributions

The reader may be able to visualize the distributions of the dependent variables (instructional methods) analyzed following this section. For the most part, distributions of dependent variables will not be shown completely for every variable. Only those contingency tables having significant comparisons will be given; a few exceptions will be made in order to present crossbreaks of each hypothesis without specifying conditions. There are certain distributions with important specifying conditions which may supply examples as to why certain crossbreaks may lack enough responding teachers for significance. A few such distributions are given in Table Seven.

Table Seven lists the frequencies of teachers using certain methods in specific subjects and with certain levels of students. The table represents two contingency tables, not a three-way crossbreak. Percentages are included with the frequency data for the first table, which concerns student level. The contrast in methods for high level first course students is provocative; these data are presented in this thesis without discussion since they do not relate to any specific hypothesis nor to the general hypothesis.

Table Seven may also suggest that teachers were candid in their responses; various alternatives are well represented in the sample.

TABLE 7

FREQUENCIES OF TEACHERS USING CERTAIN METHODS IN SPECIFIC COURSES AND WITH SPECIFIC LEVELS OF STUDENTS

Non-spatial Independent Variable Course[a]	Dependent Variables[a]						
	VAR(105), X(54) Lab Centered		VAR(119), X(44) if X(43) = 1 Inquiry Minimal Wet Lab		VAR(134), X(47) Percent Individual Projects		
	Yes	No	Inquiry Wet	Not So	Few, if any	Some	Compulsory
VAR(135), X(13)	Level of Student						
High First	51[b](60%)	34(40%)	57(73%)	21(27%)	33(39%)	37(43%)	15(18%)
Ave. First	104(39%)	161(61%)	87(37%)	151(63%)	154(58%)	87(33%)	24(9%)
Low First	31(40%)	47(60%)	20(39%)	31(61%)	54(69%)	16(21%)	8(10%)
Mixed First	3(25%)	9(75%)	1(13%)	7(87%)	5(42%)	7(58%)	..(..)
Adv. Place.	11[c](48%)	12(52%)	4(18%)	18(82%)	8(35%)	11(48%)	4(17%)
High Second	13[d](81%)	3(19%)	9(60%)	6(40%)	3(19%)	3(19%)	10(62%)
Ave. Second	11(65%)	6(35%)	8(53%)	7(47%)	6(35%)	4(24%)	7(41%)
VAR(43), X(11)	Subject						
Earth Science	18(36%)	32(64%)	17(43%)	23(57%)	24(48%)	20(40%)	6(12%)
Gen. Science	1(10%)	9(90%)	..(..)	3(100%)	9(90%)	1(10%)	..(..)

TABLE 7 -- Continued.

Non-spatial Independent Variable Course[a]	Dependent Variables[a]						
	VAR(105), X(54) Lab Centered		VAR(119), X(44) if X(43) = 1 Inquiry Minimal Wet Lab		VAR(134), X(47) Percent Individual Projects		
	Yes	No	Inquiry Wet	Not So	Few, if any	Some	Compulsory
VAR(43), X(11)	Subject						
Phys. Sci	5(28%)	13(72%)	5(56%)	4(44%)	13(72%)	4(22%)	1(6%)
Biology	107(52%)	98(48%)	75(41%)	110(59%)	97(47%)	69(34%)	39(19%)
Chemistry	56(47%)	63(53%)	40(38%)	66(62%)	69(58%)	39(33%)	11(9%)
Physics	29(38%)	47(62%)	42(59%)	29(41%)	44(58%)	25(33%)	7(9%)
Integrated	5(50%)	5(50%)	6(75%)	2(25%)	3(30%)	5(50%)	2(20%)
Anat. -Physio.	3(43%)	4(57%)	..(..)	4(110%)	3(43%)	2(29%)	2(28%)
	Total Teachers Using Instructional Methods[e]						
Column Totals	224 (45%)	272 (55%)	186 (44%)	241 (56%)	263 (53%)	165 (33%)	68 (14%)

[a] See Appendices A and B for explicit definitions.

[b] VAR(106) indicates 27% of these 51 teachers are inquiry oriented.

[c] VAR(106) indicates 46% of these 11 teachers are inquiry oriented.

[d] VAR(106) indicates 31% of these 13 teachers are inquiry oriented.

[e] The count is based on VAR(135) analysis since this variable's categories included all teachers.

The table also demonstrates the fine distinctions made in some dependent variables.

Specific Hypotheses

The tests and measures of significance used in this section are discussed in Appendix D. However, brief mention of conventions and abbreviations will be made here.

Each hypothesis will be presented first for evaluation without specifying non-spatial conditions. The number of responding teachers will be entered in the appropriate cell of the contingency table. This number represents the number of teachers who answered two questions on the questionnaire in such a way as to place them in a category represented by a cell of the contingency table. These cells are labeled by a letter which is used as a column label when summarizing cell distributions with non-spatial specifiers. Such labeling will allow the reader to construct his own contingency table if he wishes.

Following the presentation of the unconditional crossbreak, a table is presented which shows how associational values may be increased through the use of non-spatial specifiers. These new crossbreaks are the same as originally presented, but consider only those answers from teachers who meet certain contingent non-spatial conditions. Up to three conditions are specified; beyond this number, the number of teachers becomes too small for analysis. In order to save space, the frequency of teachers in each cell is not diagrammed as was done earlier; the frequencies are presented in columns labeled as explained above.

The labeling of specified crossbreaks is done in abbreviated style. The abbreviations are sufficient for the reader who is well acquainted with the variables. At first the reader will have to consult Appendix B for specific definitions of the variables. The most exact label of the variable is its number appearing in the column labeled "VAR." This number has a more lengthy label in Appendix B. The label includes a data variable number preceded by an "X"; this number is keyed to a specific question in Appendix A. Appendix A can supply operational definitions for the variables being considered. The categories of variable values are defined in the right hand parenthesis of the definition in Appendix B. If the raw data are used as an interval variable of many values, no parentheses will exist. This situation only would occur with a few parametric tests.

Not every hypothesis has the same type of analysis. Tests and associational measures appropriate for the data are included in the crossbreak tables. The following abbreviations are used in the tables:

1) Test = test used for significance measure;
2) Fisher = Fisher exact probability test;
3) Yates = chi-square test with Yates' correction for continuity;
4) Chi = chi-square test;
5) K-S = Kolmorgorov-Smirnov test;
6) Tau CS = Stuart's method for determining significance using Kendall's tau c;
7) F = one-way analysis of variance;
8) t = Student's t-test;

9) Sig. = significance;

10) Phi = phi coefficient;

11) V = Cramer's V coefficient;

12) C = contingency coefficient;

13) Tau B, Tau C = Kendall's tau statistics, b or c;

14) G = Goodman-Kruskal gamma statistic;

15) D = Sommer's D statistic, when not specifying a frequency in cell D;

16) r = Pearsonian correlation coefficient;

17) r_{pbi} = point-biserial correlation coefficient;

and 18) Max. Phi = approximate maximum phi coefficient.

Only those crossbreaks showing distributions significantly different from chance (alpha level being .05) are shown. Some statistically significant crossbreaks may be omitted if they are low in associational value or are somewhat redundant considering other analyses presented. Although most hypotheses were presented with a rationale allowing one-tailed significance levels, alpha levels are set for two-tailed tests in all but the Fisher exact tests. Significance levels presented in the tables represent two-tailed tests except when "Fisher" is specified as the test. One-tailed results are computed by the Fisher exact test; doubling of this figure will supply the reader with a two-tailed test of probability.

Hypothesis One

Although the rationale presented for this hypothesis[1] may justify a one-tailed test of significance, two tailed tests have been used in the following analysis--except for the Fisher exact tests. Table Eight presents the main comparison of departmental access to the library and the giving of library instruction. No problems of scaling occurred for the two variables, VAR(46) and VAR(79).

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[1] Supra, pp. 25-26.

TABLE 8

CONTINGENCY TABLE FOR HYPOTHESIS ONE

		VAR(79), Library Instruction	
		Yes	No
VAR(46) Library Access	Direct	68 A	105 B
	Indirect	C 77	D 245

Sig. = .001 Test = Yates C = .159

Phi = .161 Max. Phi = .90

It is evident from Table Eight that a significant relation does exist which associates library use (as defined by the interview schedule, Appendix A) with direct departmental access to the library. The associational coefficient seems low, but may be clarified by specifying contingent conditions. Specifications for increasing the associational values are given in Table Nine.

TABLE 9

HYPOTHESIS ONE - SPECIFIED CROSSBREAKS
VAR(46) x VAR(79)

Contingent Condition	VAR	Test	Sig.	Phi	Max. Phi	C	Frequency			
							A	B	C	D
Single Specifiers Supplying Variable Code .										
Total College	11									
Low		Yates	.012	.283	.62	.272	12	27	5	52
Average		Yates	.018	.145	.89	.144	42	64	49	142
Jr. College	14									
Average		Yates	.016	.196	.73	.192	23	45	18	89
High		Yates	.032	.249	.87	.241	18	16	16	41
Grade	42									
Sophomore		Yates	.010	.223	.82	.218	27	33	22	71
Budget/Pupil	128	Yates	.004	.195	.83	.191	40	55	35	113
Course Biology	43	Yates	.015	.181	1.00	.179	35	40	37	92
Multiple Specifiers Using Variable Codes[b]										
Low (Budget) High (Jr. C.)	128 14	Fisher	.004	.629	.92	n/a[c]	9	..	5	8
High (Budget) Ave. (Jr. C.)	128 14	Yates	.005	.321	.55	.306	15	29	4	45
High (Budget) Low (Tot. C)	128 11	Fisher	.004	.567	.83	n/a[c]	6	5	1	19
Low (Budget) Old Ave.(Dept)	128 22	Yates	.010	.250	.85	.243	18	17	23	68
Ave. (Tot. C.) Earth Sci. Freshman	11 43 42	Fisher	.032[d]	.443	1.00	n/a[c]	7	3	4	12
Ave. (Tot. C.) Biology Sophomore	11 43 42	Yates	.039	.257	.74	.249	16	20	9	35

TABLE 9--Continued

Contingent Condition	VAR	Test	Sig.	Phi	Max. Phi	C	Frequency			
							A	B	C	D
High (Tot. C) Biology Sophomore	11 43 42	Fisher	.041[d]	.485	.92	n/a[c]	5.	3	2	11
Low (Tot. C.) Chemistry Junior	11 43 42	Fisher	.019	.548	.65	n/a[c]	4	3	..	9
Low (Tot. C) Biology Sophomore	12 43 42	Yates	.025	.302	.87	.289	13	13	9	34
Ave. (Jr. C.) Biology Sophomore	14 43 42	Yates	.030	.346	.61	.327	8	13	3	29

[a] The frequencies of cells are keyed in Table Eight.

[b] For definitions of variables, see the single specifier section and Appendix B.

[c] When a measure is not valid, the symbol n/a will be used.

[d] These Fisher exact test significance values are for the one-tailed test. Results are insignificant if the conservative two-tailed test is used.

Hypothesis Two

Although the rationale presented for this hypothesis[1] may justify a one-tailed test of significance, two tailed tests have been used in the following analysis. Table Ten presents the main comparison between laboratory arrangement and inquiry teaching. There was no problem with

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[1] Supra, pp. 26-28.

TABLE 10

CONTINGENCY TABLE FOR HYPOTHESIS TWO

		VAR(47), Classroom-Laboratory	
		Separate	Class-Lab
VAR(81) Inquiry vs. Product	Inquiry Wet	18 A	168 B
	Verifying	C 62	D 211

Sig. = $<$.001 Test = Yates C = .166
Max. Phi = .63 Phi = .169

the scaling of the spatial variable; but during the interview phase, another dependent variable was recognized as a less ambiguous classification.[1] VAR(81) was the original dependent variable cited in the proposal of research; first, it will be fully compared with VAR(47). Second, the alternative dependent variable, VAR(119), will be analyzed.

It is evident from Table Ten that a significant relation does exist; the null hypothesis is rejected. The associational level seems weak; by the use of specifiers, the relationship can be clarified to some extent. Table Eleven reports the results of such specification.

The ambiguity of VAR(81) led to the identification of teachers who did not use the lab enough to be lab centered, but who did approach lab

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[1] The ambiguity arises in that VAR(81) requires two conditions for classification as wet inquiry. Some inquiry teachers do not hold, on the average, one lab period per week.

TABLE 11

HYPOTHESIS TWO -- SPECIFIED CROSSBREAKS
VAR(47) x VAR(81)

Contingent Condition	VAR	Test	Sig.	Phi	Max, Phi	C	Frequency			
							A	B	C	D
Single Specifiers Supply Variable Code										
First Course Level Average	40	Yates	<.001	.266	.69	.257	5	80	46	115
Preparations/Day Two	38	Yates	.001	.236	.59	.230	7	86	36	101
Preparations/Day Over One	39	Yates	.001	.178	.52	.175	16	145	45	147
Mean Yrs. in Dept. Old Ave.	22	Yates	.006	.205	.56	.200	5	73	28	100
Multiple Specifiers Using Variable Code[a]										
Young Ave. Over One	22 39	Yates	.019	.235	.57	.227	7	68	13	35
Old Ave. Over One	22 39	Yates	.035	.179	.57	.176	5	58	23	83
Average One	40 39	Yates	.035[b]	.265	.80	.256[b]	..	21	15	49
Average Over One	40 39	Yates	.001	.284	.87	.273	5	59	31	66
Young Ave. Over One Average	22 39 40	Yates	.008	.380	1.00	.355	1	30	10	21
Two Average	38 40	Yates	<.001	.377	.71	.353	1	41	25	46

[a] For definitions of the variables, see the single specifier section and Appendix B.

[b] This contingency table had one out of four cells with an expected frequency of slightly less than four. This lends doubt to significance and the contingency coefficient. The distribution is striking when plotted as a contingency table.

exercises by inquiry methods. VAR(119) eliminates these middle ground teachers by comparing only those teachers that average at least one lab period per week. Tables Twelve and Thirteen present the data.

TABLE 12

CONTINGENCY TABLE FOR HYPOTHESIS TWO, MODIFIED

		VAR(47), Classroom-Laboratory	
		Separate	Class-Lab
VAR(119) Inquiry Minimal Wet Lab	Inquiry Wet	18 A	163 B
	Verifying	C 56	D 177

Sig. = $< .001$ Test = Yates C = .179

Max. Phi = .55 Phi = .182

Again the null hypothesis is rejected. There is doubtful significance of increase in the phi coefficient over the phi of Table Ten. Table Thirteen uses the same non-spatial variables as in Table Eleven. Only those crossbreaks improving the phi coefficient of Table Twelve are listed in Table Thirteen.

Hypothesis Three

As explained in the presentation of the rationale[1], two analyses were attempted with this hypothesis. The spatial independent variables were 1) class size usually over fifty students, VAR(49), and 2) class size occasionally over fifty students, VAR(48). Only eleven teachers usually had classes over fifty students. As a consequence, no specified crossbreak analysis was done for VAR(49). Table Fourteen presents the two main contingency tables.

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[1] Supra, pp. 28-29.

TABLE 13

HYPOTHESIS TWO MODIFIED -- SPECIFIED CROSSBREAKS
VAR(47) x VAR(119)

Contingent Condition	VAR	Test	Sig.	Phi	Max. Phi	C	Frequency A	B	C	D
Single Specifiers Supplying Variable Code										
Average	40	Yates	<.001	.281	.67	.271	5	78	43	101
Old Dept.	127	Yates	.016	.243	.90	.236	4	32	28	53
Two Preps.	38	Yates	.001	.248	.66	.240	7	84	33	88
Multiple Specifiers Using Variable Code										
Average One Prep.	40 37	Yates	.028[a]	.294	.80	.282[a]	..	14	20	40
Average Two Preps.	40 37	Yates	<.001	.381	.76	.356	1	23	41	43

[a] See footnote b to Table Eleven.

Statistical interpretation of Table Fourteen is hampered by uneven distribution of marginal frequencies. The null hypothesis is definitely not rejected when considering teaching assignments with usually large classes. The presence of small cells usually gives spurious significance; a significance value of .06 should be considered a lower limit.

The question of occasionally teaching large classes involves team teaching. Such large classes, which are usually lecture, do tend to have several teachers sitting in on the lecture. The significance of these findings is not only statistically doubtful, but practically inconsequential.

TABLE 14

CONTINGENCY TABLES FOR HYPOTHESIS THREE

Usually Teaching Large Classes

		VAR(82), Cooperative Teaching	
		No	Yes
VAR(49), Large Class, Usual	No	469 A	15 B
	Yes	C 9	D 2

Sig. = .060[a] Test = Yates C = .121[a]

Phi = .122 Max. Phi = .80

Occasionally Teaching Large Classes

		VAR(82), Cooperative Teaching	
		No	Yes
VAR(48), Large Class, Infrequent	No	464 A	10 B
	Yes	C 14	D 7

Sig. = < .001[a] Test = Yates C = .327[a]

Phi = .346 Max. Phi = .80

---

[a] One cell out of the four has an expected frequency less than one. This invalidates these statistics based on chi-square analysis.

Table Fifteen shows the results of specification attempts with VAR(48). It must be remembered that only a few schools could be supplying the teacher respondents for cells. All crossbreaks have cells with less than five expected teachers.

TABLE 15

HYPOTHESIS THREE -- SPECIFIED CROSSBREAKS
VAR(48) x VAR(82)

Contingent Condition	VAR	Test	Sig.	Phi	Max. Phi	C	Frequency			
							A	B	C	D
Single Period Length	24-26									
Short Ave.	24	Yates	<.001[a]	.390	.90	.364[a]	270	9	10	7
Shorter	25	Yates	<.001[a]	.341	.90	.323[a]	282	10	13	7

[a] These statistics are invalid since they are calculated with chi-square statistics which were based on one cell out of four having a frequency of less than five.

Hypothesis Four

The sample of schools in this survey did not yield any very large laboratory groups as mentioned in the rationale.[1] The hypothesis was evaluated on existing data with a limited range of the number of students in a single laboratory class. The Kolmogorov-Smirnov two sample test was used as a highly sensitive test for significance in distribution difference. The null hypothesis was not rejected. The Data-Text program isolated two frequency distributions defined by the following criteria:

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[1] Supra, pp. 29-30.

1) Team -- Number in Lab: X(21) if X(46) = 1

2) Solitary -- Number in Lab: X(21) if X(46) = 2.

Table Sixteen presents the data used in analysis and cumulative percentage frequency distributions.

The maximum difference in cumulative frequency percentage was 0.09. The significance of this difference was calculated according to procedures outlined in Siegel's text.[1]

$n_1 = 41$ teachers, $n_2 = 448$ teachers

$$\text{Critical D at .05 level} = 1.36\sqrt{\frac{n_1 + n_2}{n_1\, n_2}}$$

$$\text{Critical D} = 1.36\sqrt{\frac{489}{18368}} = .222$$

Observed D = 0.09

Since the observed D did not equal or exceed the critical D, the null hypothesis is not rejected.

Hypothesis Five

The rationale for this hypothesis is given on page thirty. Of those teachers for whom outdoor areas were relevant, only seven did not have walking access to an outdoor teaching area. No analysis was valid with this small frequency.

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[1] Siegel, pp. 127-136, 279.

TABLE 16

HYPOTHESIS FOUR -- KOLMOGOROV-SMIRNOV TEST FREQUENCY COMPARISON OF X(46) RESPONSES

Number in Lab	Team Approach, X(46) = 1		Solitary Approach, X(46) = 2		D
	Frequency (f)	Cumulative f%	Frequency (f)	Cumulative f%	
3	1	.02	1	.00	.02
4	..	.02	..	.00	.02
5	..	.02	1	.00	.02
6	..	.02	3	.01	.01
7	1	.05	2	.02	.03
8	..	.05	4	.02	.03
9	..	.05	4	.03	.02
10	3	.12	8	.05	.07
11	1	.15	5	.06	.09
12	..	.15	20	.11	.04
13	..	.15	10	.13	.02
14	1	.17	13	.16	.01
15	1	.20	20	.20	.00
16	1	.22	18	.24	.02
17	..	.22	19	.29	.07
18	1	.24	20	.33	.09
19	2	.29	13	.36	.07
20	3	.36	40	.45	.09
21	3	.44	17	.49	.05
22	3	.51	52	.60	.09
23	4	.61	38	.68	.07
24	6	.76	26	.74	.02
25	5	.88	30	.81	.07
26	1	.90	22	.86	.04
27	1	.93	21	.90	.03
28	2	.98	16	.94	.04
29	1	1.00	10	.97	.03
30	..		7		
31	..		2		
32	..		3		
33	..		2		
34	..		..		
35	..		1		

Hypothesis Five Prime

The rationale[1] for this hypothesis may justify one-tailed tests of significance, but two-tailed tests were used. Table Seventeen presents the main crossbreak. The spatial independent variable presents no problems in classification. The dependent variable, percent of individual projects, was interval-ratio in nature, but the variable did not have a normal distribution.[2] This necessitated ordinal or nominal, non-parametric analyses. The curve was not normalized since the population distribution was not assumed to be normal.

TABLE 17

CONTINGENCY TABLE FOR HYPOTHESIS FIVE PRIME

		VAR(87), Percent of Individual Projects			
		None	Few	Several	Compulsory
VAR(54) Outdoor Area Type	Developed	49 A	22 B	42 C	9 D...F
	Undeveloped	G 147	H 43	I 123	J...L 58

Sig. = .057 Test = Chi V = .124 C = .123

Tau C = .055 G = .107 D = .074

Although significant for a one-tailed test, the main crossbreak is not significant for a two-tailed test. A Kolmogorov-Smirnov test does not reveal significant differences between the two rows. In fact, several Kolmogorov-Smirnov tests done on specified crossbreaks never revealed any significant difference. Table Eighteen gives the results of specification with non-spatial variables.

---

[1] Supra, pp. 30-31.

[2] For the distribution of VAR(84): mean = 20%, median = 3%, standard deviation = 34, skewness = 1.684, and kurtosis = 1.110 (definitions, supra, p.81.)

It is apparent that the null hypothesis can only be rejected in reference to average students in first level science courses. It is the general impression of the investigator that very few outdoor projects were being done by students in science classes.[1]

TABLE 18

HYPOTHESIS FIVE PRIME -- SPECIFIED CROSSBREAKS
VAR(54) x VAR(85, 87)

Test	Sig.	V	C	Tau C	G	D	Frequency											
							A	B	C	D	E	F	G	H	I	J	K	L
One Preparation Per Day, VAR(37) -- VAR(85) versus VAR(54)																		
Tau CS	no	.238	n/a	.101	.201	.268	12	4	4	5	..	..	36	7	20	11	7	6
Average First Course Level, VAR(40) -- VAR(87) versus VAR(54)																		
Chi	.036	.180	.177	.057	.108	.074	27	17	23	1			81	29	64	22		

Hypothesis Six

The concern for the utilization of school sites now shifts to a different aspect. Does minimal class use of the outdoor area increase for outdoor inquiry study when undeveloped areas are present? The rationale is presented on page thirty-one. No classification problems occurred for the spatial or dependent variables. Table Nineteen presents the main crossbreak.

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[1] Some students were working outdoors in connection with vocational agriculture classes, but science classes were rarely integrated with this work.

TABLE 19

CONTINGENCY TABLE FOR HYPOTHESIS SIX

VAR(54) Outdoor Area Type		VAR(90), Outdoor Problem Solving	
		Yes	No
	Developed	22 A	66 B
	Undeveloped	C 99	D 149

Sig. = .018 Test = Yates C = .135

Max. Phi = .79 Phi = .137

TABLE 20

HYPOTHESIS SIX -- SPECIFIED CROSSBREAKS
VAR(54) x VAR(90)

Contingent Condition	VAR	Test	Sig.	Phi	Max. Phi	C	Frequency			
							A	B	C	D
Mean Yrs. in Dept. Old Ave.	22	Yates	.042	.183	.70	.180	9	28	50	61
Prep/Day Over One	39	Yates	.026	.145	.77	.144	20	53	84	110

It is evident from Table Nineteen that the null hypothesis is rejected; a small association exists. The associational values were difficult to improve by specification, as shown in Table Twenty.

Hypothesis Seven

Although the rationale for this hypothesis[1] may justify a one-tailed test of significance, two-tailed tests have been used except for the Fisher exact tests. The spatial variable, VAR(55), presents no classification problems. The dependent variable has numerous classifications used throughout the analysis. Table Twenty-one presents the main cross-breaks and one which eliminates those teachers requiring individual projects.

TABLE 21

CONTINGENCY TABLES FOR HYPOTHESIS SEVEN

		VAR(85), Percent Individual Projects					
		None	1%	Few	10-20%	Heavy	Compulsory
VAR(55) Individual Lab Space	Available	107 A	22 B	60 C	64 D	33 E	49 F...G
	Not Available	K 90	L 4	M 29	N 15	O 3	P...Q 19

Sig. = $<$.001 Test = Chi V = .270 C = .260

Tau C = .225[a] G = .343 D = .257

---

[1] Supra, pp. 31-32.

TABLE 21 -- Continued

The Table Most Used

		VAR(87), Percent Individual Projects			
		None	Few	Several	Compulsory
VAR(55) Individual Lab Space	Available	107 A	45 B	134 C	49 D
	Not Available	K 90	L 20	M 31	N 19

Sig. = <.001 Test = Chi V = .248 C = .241

Tau C = .219 G = .353 D = .250

The Table Not Including Compulsory Category

		VAR(89), Percent Individual Projects	
		None	Some
VAR(55) Individual Lab Space	Available	107 A	179 B
	Not Available	K 90	L 51

Sig. = .001 Test = Yates C = .242

Max. Phi = .77 Phi = .249

---

[a] Tau C on the longest dependent variable for this hypothesis, VAR(126), was 0.234.

It is evident that the null hypothesis is rejected and that low associational values do exist. Table Twenty-two shows the results of attempts to improve the associational values by specification of contingent conditions; only the crossbreaks producing the highest associational values are shown.

TABLE 22

HYPOTHESIS SEVEN — SPECIFIED CROSSBREAKS
SPATIAL I.V. = VAR(55)

Contingent Condition	VAR	D.V. VAR	Test	Sig.	Phi[a] V	Max Phi	C	Tau C	G	D	Frequency A	B	C	D	E	F	G	K	L	M	N	O	P	Q
Single Specifiers Supplying Variable Code																								
Tot. Col.																								
Entrants	11-12																							
Lower	12	85	Chi	.035	.225	n/a	.219	.184	.289	.206	61	11	23	29	11	23		47	3	12	6	2	10	
Higher	12	85	Chi[b]	<.001	.315	n/a	.301	.257	.386	.297	44	10	37	32	20	24		42	1	16	8	1	9	
Lower	12	89	Yates	.005	.209	.78	.204	n/a	.425	.220	61	47						74	23					
Higher	12	89	Yates	<.001	.295	.82	.283	n/a	.568	.310	44	42						99	26					
Higher	12	133	Yates	<.001	.295	.82	.283	n/a	.611	.312	69	54						74	14					
First Level	40																							
Low	40	87	Chi	.047	.320	n/a	.304	.297	.464	.300	18	7	13	5				25	4	3	3			
Low	40	134	Chi	.043	.284	n/a	.273	.229	.479	.231	25	13	5					29	3	3				
Low	40	89	Yates	.017	.315	.87	.300	n/a	.597	.308	18	20						25	7					
Average	40	85	Chi	.001	.277	n/a	.267	.216	.343	.251	60	17	40	32	13	19		47	1	20	9	1	5	
Average	40	134	Chi	.006	.197	n/a	.193	.180	.387	.209	93	69	19					60	18	5				
Average	40	88	Yates	.001	.222	.82	.217	n/a	.449	.235	60	121						47	36					
Average	40	89	Yates	.001	.219	.76	.214	n/a	.441	.232	60	102						47	31					
High[c]	40	87	Chi	.005	.299	n/a	.287	.085	.148	.107	60	33	69	19				47	13	18	5			
High	40	89	Yates	.024	.304	.69	.291	n/a	.618	.345	16	37						11	6					
Preps/Day	37-39																							
One	37	89	Yates	.047	.215	.77	.210	n/a	.445	.235	28	46						19	12					
Two	37	86	Chi	<.001	.288	n/a	.277	.282	.419	.306	49	23	49	12	28			54	9	17	2	9		
Two	37	126	Chi	.001	.298	n/a	.286	.294	.426	.318	49	36	23	17	5	3	28	54	17	5	4	1	1	9
Three	37	87	Chi	.027	.292	n/a	.280	.060	.092	.068	23	6	34	10				15	5	6	9			

TABLE 22--Continued.

Contingent Condition	VAR	D.V. VAR	Test	Sig.	Phi[a] V	Max Phi	C	Tau C	G	D	Frequency													
											A	B	C	D	E	F	G	K	L	M	N	O	P	Q
Multiple Specifier Using Variable Code																								
Two Preps Low Level	38 40	87	K-S	.05	.509	n/a	n/a	.490	.816	.490	8	4	4	3				17	1	1	..			

[a] When a table is 2 x 2, V equals Phi.

[b] A large sample K-S test yields .001 significance.

[c] This does not meet the alpha significance for a two-tailed test.

Hypothesis Eight

Although the rationale[1] for this hypothesis may justify a one-tailed test of significance, the variation in age of junior high school buildings caused a wide diversity in opportunities for biology teaching -- thereby indicating the appropriateness of a two-tailed test. Some junior high schools were well located for ecology field trips and often had well stocked supply rooms. Rarely did the junior high school have the large ancillary facilities justified in high schools. This latter point provides justification for one-tailed tests, although the risk is high.[2]

The small numbers involved with this hypothesis often made it necessary to use the Fisher exact test. It is difficult to attain a two-tailed alpha of .05 with low frequencies. As usual, one-tailed tests are reported with the Fisher tests.

Table Twenty-three presents the obviously insignificant main comparison. Associational measures are not given because of the lack of significance. The null hypothesis is not rejected by the comparison in Table Twenty-three, but specification may eliminate masking factors. Table Twenty-four presents one significant crossbreak[3] and two insignificant crossbreaks useful in showing the variability in junior high biology teaching.

---

[1] Supra, p. 32.

[2] The involved risk pertains to the possibility that a significant opposite relationship could be found. With one-tailed prediction, the investigator is obligated) ignore such significant results.

[3] A one-tailed Fisher exact test was used.

It appears that under certain circumstances, the location of ninth grade biology does make a significant difference in teaching methods. This phenomenon will be discussed in the next chapter.

TABLE 23

CONTINGENCY TABLE FOR HYPOTHESIS EIGHT

		VAR(77), Junior or Senior High School Biology	
		Junior	Senior
VAR(81) Inquiry vs. Product	Inquiry	10 A	17 B
	Product	C 10	D 15

Test = Yates   Not significant

TABLE 24

HYPOTHESIS EIGHT — SPECIFIED CROSSBREAKS
VAR(77) x VAR(81)

Contingent Condition	VAR	Test	Sig.	Phi	Max Phi	C	Frequency A	Frequency B	Frequency C	Frequency D
Preps/Day	38									
Two		Fisher	.032	.412	.80	n/a	1	11	8	9
One		Fisher	1.00	n/a	n/a	n/a	..	..	..	6
Above two		Fisher	.404	n/a	n/a	n/a	9	6	2	..

Hypothesis Nine

Although the rationale[1] for this hypothesis may justify a one-tailed test of significance, the conservative use of two-tailed tests proved to be of value when conditions of darkening were trichotomized. Table Twenty-five gives the main crossbreaks for the two variations of the independent spatial variable. Since the number of films shown per year was normally distributed, division of this variable at the mean was equally justified as that at the median. Parametric tests were also done, as reported in Table Twenty-six.

There appears to be little relation between ability to darken rooms and the number of films shown. If first year teachers are eliminated from the analysis, results are still essentially the same. Table Twenty-seven presents the significant results of specification attempts.

Hypothesis Ten

Although the rationale[2] is stated so that a one-tailed test of significance would be proper, a two-tailed test is being applied. Table Twenty-eight presents the main crossbreak. The null hypothesis is rejected; closed circuit television does lead to significantly more use than broadcast television. However, disuse is high and the associational values are low. Table Twenty-nine presents the significant results of specification.

---

[1] Supra, pp. 32-33.

[2] Supra, p. 33.

TABLE 25

CONTINGENCY TABLES FOR HYPOTHESIS NINE

Trichotomous Spatial Variable

VAR(136), Films/Year

		Below Mean	Above Mean
VAR(57) Darkenable for films	Yes	213 A	145 B
	Poorly	40 C	32 D
	No	52 E	13 F

Sig. = .004 Test = Chi C = .148

Tau C = .080 V = .150

Dichotomous Spatial Variable

VAR(136), Films/Year

		Below Mean	Above Mean
VAR(140) Darkenable for films	Yes	213 A	145 B
	No	E 52	F 13

Sig. = .003 Test = Yates C = .151

Max. Phi = .55 Phi = .153

Hypothesis Eleven

Once again, the conservative practice of using two-tailed tests (except with Fisher exact tests) allows the reversal of the original thinking[1] leading to the hypothesis. The main crossbreak is presented in Table Thirty. When subsequent crossbreaks lacked sufficient cell size, the distribution of lab cost was split at the median (VAR 8).

TABLE 26

PARAMETRIC TESTS FOR HYPOTHESIS NINE
VAR(57, 140) x VAR(94)

VAR(57) Value	Films Shown Per Year, VAR(94)		
	Mean	Standard Deviation	N
1 Yes	14.4	10.4	358
2 Poor	17.9	12.2	72
3 No	12.0	9.7	65
Total 1, 2, 3	14.59	10.7	495
Total 1, 3	14.04	10.3	423

Trichotomous F-test Variation:

Source	Mean Square	DF
Between Groups	609.16	2
Within Groups	111.636	492

F-test = 5.452 $p = .005$ r = n/a

Dichotomous F-test Variation:

Source	Mean Square	DF
Between Groups	318.94	1
Within Groups	105.30	421

F-test = 3.029 $p = .083$ $r_{pbi} = -.085$

---

[1] Supra, pp. 33-34.

TABLE 27

HYPOTHESIS NINE — SPECIFIED CROSSBREAKS
D.V. = 95, 96, 136, 137 I.V. = 57, 140

Contingent Condition	VAR	D.V. VAR	Test	Sig.	Phi V	Max Phi	C	Tau C	G	D	Frequency A	B	C	D	E	F
Dichotomous Variable — VAR(140)																
Course Sub. Earth Sci.	43	136	Tau CS	no	.424	.46	.390	n/a	1.00	.590	16	23			7	..
First Course Lev. Average	40	136	Yates	.002	.222	.54	.216	n/a	.653	.296	108	83			31	5
Double Per./Wk	28															
None		136	Yates	.008	.207	.43	.203	n/a	.608	.302	84	82			21	5
Two		136	Yates	.020	.260	.55	.251	n/a	.819	.352	108	83			31	5
Single Per./Wk Modal	31	136	Yates	.010	.178	.60	.175	n/a	.527	.234	119	84			32	7
Trichotomous Variable -- VAR(57)																
Double Per./Wk	28															
None		136	Chi	.006	.214	n/a	.209	.088	.205	.103	84	82	14	20	21	5
One		137[a]	Chi	.018	.253	n/a	.245	-.135	-.108	-.041	63	28	14	5	5	10
Two		136	Chi	.025	.250	n/a	.243	.138	.344	.160	50	36	9	8	14	1
Single Per./Wk Modal	31	136	Chi	.018	.166	n/a	.164	.103	.238	.110	119	84	28	21	32	7

[a] This variable is formed by splitting at the median rather than the mean. VAR(136) has been split at the mean.

TABLE 28

CONTINGENCY TABLE FOR HYPOTHESIS TEN

		VAR(98), Television Per 10 Weeks		
		None	Once	Some-much
VAR(58) Type of T.V.	Closed Circuit	62 A	11 B	9 C
	Broadcast	224 D	17 E	4 F

Sig. = $<$.001 Test = Chi V = .236

Tau C = .123 G = .550 D = .164

TABLE 30

CONTINGENCY TABLE FOR HYPOTHESIS ELEVEN

		Cost Per Lab Period					
		$ .50 1.25	1.26 1.75	1.76 2.25	2.26 2.75	2.76 min. 9.99 max.	VAR(7)
VAR(59) Central Storage	Yes	7 A	6 B	31 C	10 D	31 E	
	No	65 F	58 G	101 H	50 I	127 J	

$ .50- 2.05 over 2.05 } VAR(8) frequencies not given here.

VAR(7): Sig. = .045 Test = Chi C = .140 V = .142

Tau C = -.070 G = -.162 D = -.122

TABLE 29

HYPOTHESIS TEN -- SPECIFIED CROSSBREAKS
VAR(58) x VAR(98, 100)

Contingent Condition	VAR	D.V. VAR	Test	Sig.	Phi V	Max Phi	C	Tau C	G	D	Frequency					
											A	B	C	D	E	F
Grade	42															
Ninth		98	Chi	.009	.382	n/a	.357	.173	.499	.233	10	1	5	40	7	2
Ninth		100	Yates	.010	.378	.57	.353	n/a	.829	.272		11	47		5	2
Budget/Pupil	128															
High		98	Chi	.001	.286	n/a	.275	.165	.628	.202	37	7	7	116	8	2
High		100	Yates	.003	.250	.38	.243	n/a	.816	.121		44	7		124	2
VAR(42+128)																
Ninth	42															
High	128	100	Fisher	.018	.484	.50	n/a	n/a	1.00	.300		7	3		25	..

It is evident that central storage is significantly, but weakly, associated with increased cost per lab period. The crossbreak with a split at the median (VAR 8) also reflected the same conclusion. Specified crossbreaks are shown in Table Thirty-one; certain conditions have antithetical conclusions.

Hypothesis Twelve

The rationale[1] for this hypothesis does not predict a rejection of the null hypothesis. Table Thirty-two presents the main crossbreak.

TABLE 32

CONTINGENCY TABLE FOR HYPOTHESIS TWELVE

		VAR(110), Use of Living Plants	
		Experimental	Not So
VAR(75) Greenhouse Available	Yes	52 A	40 B
	No	C 59	D 64

Sig. = .270 Test = Yates Phi = .085

Without the aid of specifiers, it appears that the presence of a greenhouse does not affect the use of plants by biology and earth science teachers.[2]

---

[1] Supra, p. 34.

[2] The question for data variable X(38) limits responses to these teachers as far as VAR(75) is concerned.

TABLE 31

HYPOTHESIS ELEVEN -- SPECIFIED CROSSBREAKS
VAR(59) x VAR(7, 8)

Contingent Condition	VAR	D.V. VAR	Test	Sig.	Phi V	Max Phi	C	Tau C or B	G	D	Frequency									
											A	B	C	D	E	F	G	H	I	J
Single Specifiers Supplying Variable Code																				
Tot. College	11,12																			
Average	11	7	K-S	<.001	.253	n/a	n/a	-.067	-.155	-.118	..	..	6	..	7	15	6	21	..	34
Lower	12	7	K-S	.005	.144	n/a	n/a	-.020	-.036	-.028	7	5	17	10	14	25	33	36	40	47
School Size	17-20																			
0-1435	20	7	Chi	.013	.219	n/a	.214	-.137	-.266	-.198	2	3	18	9	27	19	43	40	34	71
1436-3000	20	8	Yates	.037	.155	.44	.153	+.098	+.517	+.236	21	9				111	83			
751-1500	18	7	Chi	.002	.266	n/a	.257	-.172	-.369	-.270	2	1	15	4	26	32	30	37	28	67
1501-2250	18	8	Yates	.004	.252	.42	.244	+.156	+.859	+.393	16	1				74	61			
751-1000	17	7	Tau CS	<.001	.508	n/a	n/a	-.434	-.895	-.563	..	1	..	..	18	..	20	9	5	20
751-1000	17	8	Yates	.001	.432	.71	.397	-.373	-.909	-.484	1	18				29	25			
1001-1250	17	8	Yates	<.001	.448	1.00	.408	+.336	+.797	+.455	12	8				9	53			
Mean Years in Dept.	22																			
Young Ave.		7	Chi	<.001	.321	n/a	.305	-.173	-.283	-.219	2	3	13	8	21	16	32	12	25	41
Multiple Specifiers Using Variable Code																				
Young Ave. 751-1000	22 17	8	Yates	<.001	.638	.78	.538	-.582	-.951	-.690	1	12				23	7			
Young Ave. 1001-1250	22 17	8	Yates	.001	.528	.86	.467	+.474	+.846	+.507	12	7				4	28			

The use of grade as a specifier produced one significant[1] relation out of all those screened. The sophomore level (mostly biology) teachers produced the crossbreak presented in Table Thirty-three.

TABLE 33

HYPOTHESIS TWELVE -- SPECIFIED CROSSBREAK
VAR(75 x VAR(110)
SOPHOMORE GRADE, VAR(42)

		VAR(110), Use of Living Plants	
		Experimental	Not So
VAR(75) Greenhouse Available	Yes	35	19
	No	38	44

Sig. = .053   Test = Yates   C = .178
Max. Phi = .88   Phi = .181

Hypothesis Thirteen

This hypothesis[2] was tested with three variations in the spatial variable. Although none of the variations produced a significant crossbreak, the three main contingency tables are shown in Table Thirty-four. The use of specifiers did not produce any significant crossbreaks.

---

[1] Since the prediction was that the null hypothesis would not be rejected, the investigator conservatively rounded the significance level to the nearest hundredth.

[2] The rationale is explained supra, p. 35, infra,

TABLE 34

CONTINGENCY TABLES FOR HYPOTHESIS THIRTEEN

Spatial Condition	Frequencies of Teachers VAR(101)		Statistical Report
	Demo-Dry Lab	Wet Lab	
Spatial VAR(72), Commercial Growth Chamber Availability			
Yes	1	43	Test = Yates
No	14	166	Sig. = none
Spatial VAR(73), Commercial Growth Chamber Availability			
Yes	1	55	Test = Yates
No	15	199	Sig. = .248
Spatial VAR(74), Commercial Growth Chamber Availability			
Yes	2	88	Test = Yates
No	14	166	Sig. = .121

Hypothesis Fourteen

Although the rationale[1] for this hypothesis would allow one-tailed tests of significance, two-tailed tests are used in this analysis. The original hypothesis was comparing VAR(62) with VAR(103). Reference to the data variable X(52) in Appendix A will show that all phases of the course were considered. Table Thirty-five shows that no significant results are gained by using VAR(103), which includes dry laboratory exercises. Specification of contingent variables failed to reject the null hypothesis.

---

[1] Supra, pp. 35-37.

TABLE 35

CONTINGENCY TABLE FOR HYPOTHESIS FOURTEEN

		VAR(103), General Approach	
		Inductive	Deductive
VAR(62) Teacher Has Own Lab	Yes	79	59
	No	154	168

Sig. = .080 Test = Yates Phi = .086

An interesting finding results when another dependent variable is used. VAR(81), which concentrates on the laboratory phase of the course, measures the same axis in methodology as did VAR(103) -- the axis of product (verifying lab) versus process (inquiry lab). Tables Thirty-six and Thirty-seven present the main, insignificant crossbreak and the only specified crossbreak which is significant.

Hypothesis Fifteen

The rationale[1] presented for this hypothesis is best evaluated with two-tailed tests. Frequency distributions were such that the independent variable, size of largest sink, was utilized in two forms. VAR(76) includes the category, no sink; VAR(138) does not include this category. There are also two forms of the dependent variable:

---

[1] Supra, p. 37.

1) VAR(109) which is an extended categorization and, 2) VAR(129) which is formed by a median division for condensing cell frequencies under specification. When tau CS or chi square statistics do not yield significant results with VAR(109), the Kolmogorov-Smirnov Test can be applied when VAR(129) is used. Table Thirty-eight presents the general crossbreak.

TABLE 36

CONTINGENCY TABLE FOR HYPOTHESIS FOURTEEN
USING LAB CENTERED VARIABLE

		VAR(81), Process vs. Product	
		Inquiry Wet	Verifying
VAR(62) Teacher Has Own Lab	Yes	62	76
	No	124	196

Sig. = .258 Test = Yates Phi = .058

The null hypothesis is rejected, but weak associational values may be the result of table condensation for significance tests. Table Thirty-nine presents a few crossbreaks with specifications. Some crossbreaks have no sensitive significance tests that are applicable.

TABLE 37

HYPOTHESIS FOURTEEN -- SPECIFIED CROSSBREAK[a] USING LAB CENTERED VARIABLE VAR(62) x VAR(81)

		VAR(81), Process vs. Product	
		Inquiry Wet	Verifying
VAR(62) Teacher Has Own Lab	Yes	28	14
	No	54	64

Sig. = .032 Test = Yates Phi = .184

Max. Phi = .60 C = .181

[a]The non-spatial condition for this crossbreak is that responding teachers belong to a young science department -- VAR(22), Young Average (Mean Years in Department).

TABLE 38

CONTINGENCY TABLE FOR HYPOTHESIS FIFTEEN

		VAR(76), Size of Largest Sink				
		None	Small	Medium	Large	Extra Large
VAR(129) Labs/4 weeks in Biology and Earth Science	Low	6 A	8 B	78 C	56 D	6 E
	High	.. F	4 G	39 H	54 I	10 J

Sig. = .05 Test = K-S V = .226

Tau C = .218 Gamma = .360 D = .177

TABLE 39

HYPOTHESIS FIFTEEN — SPECIFIED CROSSBREAKS
VAR(76, 138) x VAR(109, 129)

Contingent Condition	VAR	I.V. VAR	D.V. VAR	Test	Sig.	V	C	Tau C	G	D	Frequency									
											A	B	C	D	E	F	G	H	I	J
Single Specifiers Supplying Variable Code																				
Yrs. Exper. 10-13	2	138	129	none	n/a	.658	n/a	.530	.707	.405		2	5	..	1		..	4	7	1
Subject Biology	43	76	129	Chi	.031	.231	.225	.226	.363	.183	4	8	48	42	4	..	3	33	51	8
Multiple Specifiers Using Variable Code[a]																				
10-13 Biology	2 43	138	129	none	n/a	.816	n/a	.569	1.00	.889		2	1	..	..		..	4	7	1

[a] For definitions of variables, see the single specifier section and Appendix B.

Hypothesis Sixteen

The rationale[1] for this hypothesis allows a one-tailed test of significance, but two-tailed tests will be done conservatively. Table Forty gives the main crossbreak.

TABLE 40

CONTINGENCY TABLE FOR HYPOTHESIS SIXTEEN

		VAR(78), Optically Dark		
		Yes	Other Room	No
VAR(114) Limited with Optics--Physics	Limited	10	4	8
	O.K.	41	4	9

Sig. = .037 Test = Chi C = .283 V = .295
Tau C = .248 G = .519 D = .254

The null hypothesis is rejected with weak association. Table Forty-one presents the one significant relation from specification attempts.

Hypothesis Seventeen

Although the rationale[2] for this hypothesis might allow a one-tailed test of significance, two-tailed tests are used. The main crossbreak is presented in Table Forty-two.

---

[1] Supra, pp. 37-38.

[2] Supra, pp. 38-39.

TABLE 41

HYPOTHESIS SIXTEEN -- SPECIFIED CROSSBREAK
VAR(139) x VAR(114) x VAR(26), "shorter period"

		VAR(139), Optically Dark	
		Yes	No
VAR(114) Limited with Optics--Physics	Limited	1	17
	No	6	7

Sig. = .012 Test = Fisher

Max. Phi = .67 Phi = .479

TABLE 42

CONTINGENCY TABLE FOR HYPOTHESIS SEVENTEEN

		VAR(104), Undirected Laboratory Minimum	
		At least One	None
VAR(59) Central Storage	Yes	39	46
	No	184	217

Test = Yates Not significant

The null hypothesis was not rejected in the main crossbreak; attempts to find a significant crossbreak by use of specifiers produced only one significant contingency table which is given in Table Forty-three.

TABLE 43

HYPOTHESIS SEVENTEEN -- SPECIFIED CROSSBREAK[a]
VAR(59) x VAR(104)

		VAR(104), Undirected Laboratory Minmum	
		At least One	None
VAR(59) Central Storage	Yes	17	12
	No	26	60

Sig. = .012 Test = Yates C = .247

Max. Phi = .75 Phi = .255

[a] The non-spatial condition for this crossbreak is that students involved have 181-240 minutes of class time weekly -- VAR(35), value II.

Hypothesis Eighteen and Eighteen Prime

The rationale[1] for the two variations of hypothesis eighteen justifies one-tailed tests of significance, but two-tailed tests will be used. The dependent variables are chosen so that the modal methods of teaching are examined.[2] No significant results were found with these hypotheses. Tables Forty-four and Forty-five give the main crossbreaks. There was a failure to reject the null hypotheses. Specification did not unmask any significant relations.

---

[1] Supra, pp. 39-40.

[2] Dependent data variables are X(54) and X(55).

TABLE 44

CONTINGENCY TABLE FOR HYPOTHESIS EIGHTEEN

		VAR(64), Student After-hour Access	
		Yes	No
VAR(105) Lab Centered	Yes	29	195
	No	27	245

Test: Yates Not significant

TABLE 45

CONTINGENCY TABLE FOR HYPOTHESIS EIGHTEEN PRIME

		VAR(64), Student After-hour Access	
		Yes	No
VAR(106) Modal Lab Effort was Inquiry[a]	Yes	11	77
	No	18	123

Test: Yates Not significant

[a] Affirmative answer depends on an affirmative answer for VAR(105).

Hypothesis Nineteen

Although the rationale[1] for this hypothesis allows the use of one-tailed tests of significance, two-tailed tests are used. Table Forty-six presents the main crossbreak.

---

[1] Supra, p. 40.

TABLE 46

CONTINGENCY TABLE FOR HYPOTHESIS NINETEEN

		VAR(66), Teacher After-hour Access	
		Yes	No
VAR(105) Lab Centered	Yes	108 A	29 B
	No	C 92	D 40

Sig. = .115 Test = Yates

The null hypothesis was not rejected in the unspecified crossbreak. Specification produced three significant crossbreaks presented in Table Forty-seven.

Hypothesis Nineteen Prime

The rationale for this hypothesis is essentially the same as for hypothesis nineteen. Table Forty-eight presents the insignificant main crossbreak. The null hypothesis was not rejected. Specification attempts also failed to produce significant results.

TABLE 47

HYPOTHESIS NINETEEN -- SPECIFIED CROSSBREAKS
VAR(66) x VAR(105)

Contingent Condition	VAR	Test	Sig.	Phi	Max Phi	C	G	D	Frequency			
									A	B	C	D
Single Per/wk 4-5, Modal	31	Yates	.023	.191	.65	.188	.409	.211	64	16	52	31
Double Per/wk One	29	Yates	.019[a]	.346	.38	n/a	1.00	.645	40	..	22	5
Double Per Time 40-120	130	Yates	.021[a]	.337	.34	n/a	1.00	.635	40	..	23	5

[a] Marginal frequencies actually invalidate the significance test.

TABLE 48

CONTINGENCY TABLE FOR HYPOTHESIS NINETEEN PRIME

		VAR(66), Teacher After-hour Access	
		Yes	No
VAR(106) Lab Centered Effort is Inquiry[a]	Yes	42	14
	No	71	15

Test = Yates Not significant

[a] An affirmative reply on this question must have an affirmative reply to VAR(105).

Hypothesis Twenty

The analysis of hypothesis twenty yielded no significant results.[1] The presentation of the data is not warranted since the table would be very involved for a three dimensional crossbreak. The most likely source of problems with the hypothesis is in the choices presented during the interview. Most teachers elected the microorganism or non-living choice.

General Hypothesis

No formal inferential analysis can be done on such a diverse group of specific hypotheses. Table Forty-nine lists the hypotheses with the significance of the main crossbreak test and the highest, significant associational value[2] attained by specification.

Of the ten hypotheses found statistically significant, at least three can be considered important. The general null hypothesis is rejected; in some circumstances, facilities do correlate with instructional method. There was a predominance of low associational values.

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[1] Rationale is given supra, p. 41.

[2] Gamma was not included since maximum value is attained easily. Phi is given for all 2 x 2 tables.

TABLE 49

SUMMARY RESULTS OF SPECIFIC HYPOTHESES

Hypothesis	Supra pp.	Crossbreak Results			
		Unspecified (Main)		Specified-Highest Value[a]	
		Test	Significance	Test	Association
1. Library	98-101	Yates	.001	Phi	.629
2. Classroom-Lab	101-103	Yates	.001	Phi	.380
2'. Minimal Wet	104-105	Yates	.001	Phi	.381
3. Large Classes	104-107	Yates	..	Phi	.390
4. Large Labs	107-109	K-S	..	not done	
5. Outdoor Area	108	not done		not done	
5'. Type of Area	110-111	Chi	.057	V	.180
6. Outdoor Problem	111-113	Yates	.018	Phi	.183
7. Indiv. Lab Space	113-116	Chi	<.001	V	.509
8. Jr. H.S. Inquiry	117-118	Yates	..	Phi	.412
9. Films	119-122	Chi	.004	V	.253
10. Television	119-124	Chi	<.001	Phi	.484
11. Central St. Cost	120-126	Chi	.045	Tau C	-.434[b]
12. Greenhouse	125,127	Yates	.270	Phi	.181
13. Growth Chamber	127-128	Yates	.121	..	..
14. Own Lab	128-131	Yates	.080	Phi	.184
15. Sink Size	129-132	K-S	.05	V	.231
16. Optics	133-134	Chi	.037	Phi	.479
17. Central St. -Lab	133-135	Yates	..	Phi	.255
18. Student Access	135-136	Yates	..	not done	
18'. Student Access	135-136	Yates	..	not done	
19. Teacher Access	136-138	Yates	.115	Phi	.191
19'. Teacher Access	137-138	Yates	..	not done	
20. Organisms	139	distribution did not allow analysis			

[a] All associational values have met an alpha condition of 0.05. The association yielding the highest legitimate value is listed.

[b] The direction of the association varies with conditions.

CHAPTER V

CONCLUSIONS AND ANECDOTAL DATA

This chapter will discuss the findings presented in Chapter Four. Although no search of the anecdotal records has yet been conducted, mention of anecdotal remarks will be made from general impressions remaining in the investigator's mind at the time of writing.

General Hypothesis

It appears that architectural design does influence teaching methods in high school science, and that educational specifications deserve thought so that school plant design does not conflict with the intended curriculum.[1] Architecture may not be the major influence on teaching method, but in certain situations it can be a limiting factor. Teachers must not be expected to overcome obstacles created by poor plant design. Furthermore, teachers may be unconsciously guided by certain architectural characteristics so that they see no need to change their methods.[2]

The strong conclusion voiced above should not be accepted without some reservations. Does the rejection of the general null hypothesis reflect a composite of errors, or is it reasonable that chance could account for the apparent relation between architectural design and teaching methods in science? Because positive results require one peculiar alignment of data from multifarious possibilities, it is unlikely that previously hypothesized relations would be supported fortuitously to such a large extent as in this study.[1] Many null hypotheses not rejected were evaluated by poor samples because of a miscalculation on the prevalence of certain designs or practices. Furthermore, the failure to reject a null hypothesis does not indicate strong support for the null hypothesis. The crude attempts at specifying relevant conditions of non-spatial concerns gave surprisingly good results. The fact that all variables increased, rather than decreased, their associational values when specification occurred[2], gives further indication that a reasonably significant relation does exist between space and teaching method.

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[1] This inference is supported by the data presented on page 140 and by rationale provided before the gathering of data.

[2] Hypothesis one might involve such an unconscious influence of architectural arrangement of school components.

If the apparent relation is not due to chance, what could be its causes? First, it is highly likely that this research design would lead to interviewing bias. However, it is unlikely that this bias would operate only with certain hypotheses. Bias is not indicated since some alternative hypotheses were not supported. In addition, some characteristics of design were found to have the opposite influence as hypothesized.

Second, spatial variables could be associated with other attributes of the school. The size of sinks, for instance, might be associated with the wealth of general equipment. This associative characteristic may have been the causal agent of the tendency to spend certain amounts of time in the laboratory.[1]

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[1] See supra, p. 140.

[2] See supra, pp. 98-139.

Third, teachers may have been attracted to the facilities, rather than have been influenced while serving at the school. For administrators, this interpretation is at least as useful as any hypothesis presented in this thesis.

Fourth, administrative practices could have forced utilization of existing facilities. Anecdotal remarks almost invariably indicated the contrary tendency; administrative procedures usually impeded the use of facilities (or allowed the teachers to do what they wished).

Specific Hypotheses

Table Fifty presents a summary of the findings for the various specific hypotheses. Each hypothesis is then discussed at length.

Hypothesis One (Library Usage)[2]

The library can be adjacent to the science department or separated from the science department by non-science classrooms.[3] When the library is adjacent to the science department, a significantly greater proportion of science teachers take (or often send) students to the

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[1] The number of periods per four weeks devoted to laboratory work is the dependent variable of hypothesis fifteen, supra, pp. 37, 129-132.

[2] This hypothesis was discussed supra, pp. 25-26, 98-101.

[3] "Adjacent" includes the condition where a corridor, but no non-science classrooms, may be interposed between the science department and the library.

TABLE 50

SIGNIFICANT FINDINGS OF THE SPECIFIC HYPOTHESES[a]

Characteristic of Instruction	Hypothesis Number(s)	Plant Design Promoting Instructional Characteristic	Conditions Intensifying Relation or Other Remarks
Library Instruction	1	Library next to science department	Supra, pp. 100-101: 9th or 10th grade, 11th grade low ability, junior college oriented, high science dept. budget.
Wet Inquiry Methods	2	Classroom - laboratories	Infra, p. 148 certain scheduling arrangements. Supra, p. 103: more than 1 preparation per day, average level of student, 5-8 years is average of departmental membership.
Percent of Individual Projects	5', 7	Individual lab space	Supra, p. 111: outdoor area favors slightly with average students. Supra, pp. 115-116: high college entrants, low or high ability students, maximum of two preparations per day.
Outdoor Problem Solving	6	Undeveloped outdoor area	Supra, p. 112: over one preparation per day, 5-8 years is average of departmental membership.
Inquiry Teaching	8	None significant without specification	Supra, p. 109: senior high has more inquiry when teacher has two preparations; junior high has more when teacher has more than two daily preparations.

TABLE 50--Continued.

Characteristic of Instruction	Hypothesis Number(s)	Plant Design Promoting Instructional Characteristic	Conditions Intensifying Relation or Other Remarks
Showing of Films	9	Room can be darkened	Parametric tests show doubtful significance; non-parametric are highly significant. Supra, p. 122: earth science, first level course, having no double periods or more than one; average number of single periods per week.
Use of Television	10	Closed circuit television	Meager use. Supra, p. 124: ninth grade, high science budget per pupil.
Lower Cost per Lab Period	11	Central storage	Supra, p. 126: school enrollment highly significant — 751-1000 increases cost, over 1000 decreases cost; 0-4 years average departmental membership intensifies either relationship.
Use of Living Plants	12	Not significant without specification	Supra, p. 127: greenhouse in sophomore grade makes only very slight difference.
General Inductive Approach to Instruction	14	None significant	Supra, pp. 130-131: only significant relation with teacher having own laboratory occurs when only laboratory phase of course is considered.

TABLE 50--Continued.

Characteristic of Instruction	Hypothesis Number(s)	Plant Design Promoting Instructional Characteristic	Conditions Intensifying Relation or Other Remarks
Wet Lab Work in Biology and Earth Science	15	Large size sink	Supra, p. 132: biology, with teachers having 10-13 years experience.
Optics Experiments	16	Darkenable lab room, no need to use small ancillary rooms.	Supra, p. 134: shorter periods (20-46 minutes).
Undirected Lab Work	17	Not significant without specification	Supra, p. 135: central storage only significant when students have 180-240 minutes of class per week.
Lab Centered Class	19	Not significant without specification	Supra, p. 138: 4-5 single periods per week makes after-hour self-access by teacher a favorable condition. Plants could be designed to foster self-access by teacher.

[a] The following hypotheses failed to have their null form rejected: 4, 5, 13, 18, 18', 19', 20. The following hypotheses were modified upon failing to be rejected in null form: 3, 14.

library during classtime.

There is still a large number of teachers who do not give library instruction. Teachers commonly thought that the English department should give such instruction. The low associational value may reflect that some indirect access routes provided little chance of annoying classes because of the nature of the classes.

If only teachers of introductory science subjects in early high school grades reply, the relation is stronger. Library skills are often assumed by junior and senior class teachers, unless the school has a low number of entrants into college. For those schools placing a large number of students in junior colleges, or having a low to average number of total college entrants, the response to proximity of the library is strengthened. A high budget for the science department also strengthens the relationship, possibly by correlating with a high budget for the library which makes library visits more profitable because of an abundance of resource materials. However, a high budget for the science department tends to raise rewards for staying in class or laboratory, making a visit to the library less rewarding. If the library is distant, high budget teachers tend to stay away.

Hypothesis Two (Wet Inquiry Lab Modal)[1]

This hypothesis concerning the association of wet inquiry methods with the classroom-laboratory is most important. Teachers working in classroom-laboratories significantly tend more toward wet inquiry techniques than those using separate laboratory facilities.

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[1] This hypothesis was discussed supra, pp. 26-28, 101-104, 105.

The low associational value may reflect several factors revealed by anecdotal remarks. A few schools have over-built facilities so that a laboratory is usually free for a class if the teacher wishes to have an impromptu lab. The vast majority of teachers' remarks related to the classroom-lab being used for verifying study. If labs are not taught by the discussion-lecture-recitation teacher, coordination available under one teacher in a classroom-lab facility is usually lost. If labs are still scheduled once or twice per week, classroom-labs may be as inflexible as separate classrooms and labs. Some laboratory schedules are determined by assignment of a special class of students to a double period. If a teacher conducts the laboratory for some of his students mixed with another teacher's students, the teacher would rarely break the schedule of experiments to give lab experiences to his students at appropriate inquiry times. The most appropriate administrative practice for inquiry teaching in classroom-laboratories is to give one teacher charge of discussion and laboratory. Short periods usually prevent chemistry labs from occurring except in double periods.[1] Biology, probably, could be most responsive to opportunities with single period labs. Modular scheduling with open labs (students elect time for lab in their free mods) allows team teaching without the coordination difficulties previously mentioned.

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[1] One school's schedule was centered around especially long periods for chemistry and physics -- Ithaca High School in New York.

Specification attempts reveal some factors which intensify the association between the variables. Because many second or advanced courses are not inquiry oriented, the relation holds more for first course average students. If teacher load puts a premium on organizational efficiency with two or more preparations, the advantage of a classroom-laboratory is more apparent. Young departments also tended to have less verifying classes being taught in classroom-laboratories. The mood of the department, not the length of individual experience, influenced the associational value.

The modified statement of hypothesis two was also significant. The statement was revised so that those teachers holding fewer than one wet lab per week were not considered in the analysis.

Hypothesis Three (Cooperative Assignments)[1]

The occurrence of team teaching usually enables teachers to meet together for occasional large classes. The results of the analyses could pertain only to large classes under team teaching since the nominated schools rarely had large individual loads for their teachers. The analyses were handicapped by highly skewed distributions.

Hypothesis Four (Lab Team Approach)[2]

Very large laboratories were not found in the nominated schools.

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[1] This hypothesis was discussed supra, pp. 28-29, 104-107.

[2] This hypothesis was discussed supra, pp. 29-30, 107-109.

Within the limits of variation found, there were no significant results. Anecdotal remarks indicated that teachers often introduced a few team-approached labs into the course, but rarely felt that the team approach was justified as a modal method. Those teachers who did practice the team approach, in good faith, did see its excitement and advantages.

Hypothesis Five (Outdoor Individual Projects)[1]

No analysis was possible for this hypothesis. Greater discrimination as to what was available in the outdoor area may have led to significant conclusions. There was an apparent lack of awareness of opportunities for outdoor study in many situations. Late spring and early winter were given as factors for lack of school woodlot utilization in rural New Hampshire.

Hypothesis Five Prime (Type of Area--Projects)[2]

There is general difficulty in finding significant associations between type of outdoor area and number of individual projects. Even when a significant relation is found, the associational values are extremely low. Evidently project use of undeveloped outdoor areas is not a prevalent practice. Only in a few schools was outdoor utilization thought to be relevant to the curriculum. Evidently, teachers and students lack an awareness of the potential of outdoor projects. It may be legitimately contended that for certain types of courses, outdoor projects may not be appropriate. Nonetheless, most teachers do not require individual laboratory projects to be in any certain subject area. In fact, such a requirement would preclude many long range projects of a high calibre. If students are free to choose outdoor projects, they are neglecting the challenge of outdoor research.

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[1] This hypothesis was discussed supra, pp. 30, 108.

[2] This hypothesis was discussed supra, pp. 30-31, 110-111.

Hypothesis Six (Type of Outdoor Classroom)[1]

Of teachers who have undeveloped outdoor areas, rather than developed areas, a significantly greater percentage conduct at least one inquiry field trip. The associational value is low. The question supplying answers for the dependent variable X(48), is answered by only those who feel that the outside can be utilized with the present curriculum. Associational values are raised slightly when teachers belong to a department having five to eight mean years of membership or when teachers have more than one preparation per day. Under the first contingent condition, a greater percentage of teachers take advantage of the undeveloped area than in other crossbreaks.

Outdoor problem solving activities that occur with developed outdoor areas may involve physics exercises or certain biology labs. The common biological exercise was a population study of dandelions.

Hypothesis Seven (Individual Lab Space)[2]

This hypothesis tests whether or not the percentage of individual projects is associated with available space for housing these projects in undisturbed fashion. There may have been a tendency to stretch the truth in replying, especially at the lower end of the percentage range. This is why some scales combined zero and one percent answers. Compulsory science fair projects may be carried out under administrative pressure without regard to available space for project work. Some scales eliminate the compulsory category when comparing percentage with available space. All non-specified crossbreaks were significant with low associational values. The availability of individual lab space is associated with more students doing lab projects.

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[1] This hypothesis was discussed supra, pp. 31, 111-113.

[2] This hypothesis was discussed supra, pp. 31-32, 113-116.

When the compulsory projects are not included in the set of replies, the highest associational values are found with schools having high total college enrollments and with classes having low or high ability students. When teachers have two preparations per day and teach low ability youngsters, space becomes highly associated with the undertaking of project work by low ability students.

Hypothesis Eight (Ninth Grade Biology)[1]

A consequence of placing advanced junior high school students in ninth grade biology is being evaluated with this hypothesis. Junior high schools presented a great variation in design and resources. Within one school system it may be that two different junior high schools present biology in opposite ways. The unspecified crossbreak was not significant.

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[1] This hypothesis was discussed supra, pp. 32, 117-118.

Upon specification, it was found that junior high teachers who were not "super" teachers (teaching three or more different courses), did tend to teach a product oriented biology more than high school teachers who had two preparations per day. It is interesting that all six teachers who taught nothing but ninth grade biology in senior high schools taught with product orientation.

Hypothesis Nine (Film Showing)[1]

The ability to show films conveniently in one's own classroom was slightly associated with the number of films shown. (Specification increased the associational values to some extent.) When answers indicating poor, but adequate conditions were included in the analysis, significantly more films were shown under poor conditions. This strange finding can be explained if the "labeling of conditions" is considered a dependent variable of the number of films shown. That is, teachers who showed the most films voiced the most dissatisfaction with conditions.

If all teachers felt that films could be useful, this hypothesis might have had higher associational values. Many teachers did not show films although excellent viewing conditions existed. Most complaints dealt with poorly constructed venetian blinds, inability to ventilate darkened rooms properly, or with light contamination from high hall windows.

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[1] This hypothesis was discussed supra, pp. 32-33, 119-122.

Hypothesis Ten (Television)[1]

Broadcast television was not used by teachers to any great extent since scheduling of show time was rarely coordinated with their classes. Closed circuit television was used to a greater extent than broadcast television, but utilization was still low. Probably the most use television received was in showing films in well-lighted rooms. A few projects were being carried out with television in the ninth grade. The use of closed circuit television increases with high science budget per pupil and ninth grade contingent conditions.

Hypothesis Eleven (Central Storage)[2]

It appears that high cost per lab period is weakly associated with centralized storage. Upon specification, there are certain conditions under which the cost per lab is lower in association with centralized storage. These conditions are when the school enrolls over 1000 students or when a young science department exists in a school of 1001-1250 enrollment. Very strong association with higher costs occurs with young departments in schools of 751-1000 enrollment.

Hypothesis Twelve (Greenhouse)[3]

This hypothesis is stated only as the null form; it cannot be supported in the same sense as the other hypotheses, rejection of the null hypothesis being the only possible conclusion. In its unspecified form[1] the null hypothesis was not rejected. Only biology and earth science teachers answered for data variable X(38) which is VAR(75). If the crossbreak, comparing the use of living plants and availability of a greenhouse, is limited to the sophomore grade (predominantly biology) then the relationship between the two variables does become significant. The associational value is one of the lowest for specified crossbreaks. Anecdotal remarks reveal that plants used do not come often from the school's greenhouse. Close cooperation with local greenhouses has resulted in excellent fulfillment of biological needs in some schools. A few schools have used their greenhouses with amazing success. Other schools have hired personnel having greenhouse managerial experience, however there is a tendency under these situations not to use the greenhouse for plant physiology experiments.

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[1] This hypothesis was discussed supra, pp. 33, 123-124.

[2] This hypothesis was discussed supra, pp. 33-34, 123, 126.

[3] This hypothesis was discussed supra, pp. 34, 125, 127.

The main problems with most greenhouses were poor heating, inadequate ventilation and humidity control, and too small a size to prevent overheating by the sun.

Hypothesis Thirteen (Growth Chamber)[2]

An alternative or additional facility for greenhouses is the artificially illuminated growth chamber. Expensive commercial units with fine tolerances have been on the market, and only recently some schools within the sample have begun to explore possibilities of large home-made units. The presence of a commercial growth chamber failed to affect the frequency of biology and earth science teachers using demonstrations, instead of wet labs, as a modal laboratory technique. Anecdotal remarks indicated that in all but a few cases, the growth chamber was far from the focal point of any large section of laboratory work.

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[1] See Table Thirty-two, supra, p. 125.

[2] This hypothesis was discussed supra, pp. 35, 127-128.

Hypothesis Fourteen (Own Room)[1]

This hypothesis considers the effect of teaching in one's own room rather than sharing a room. The relation was not significant. Anecdotal remarks reveal that an all important factor may be the compatibility of teachers sharing the room. Another factor to be considered is the possibility that one teacher considers it his room, although it is shared. The floating teacher who had no room of his own, often complained of that situation.

As suggested in the rationale[2], the teacher's office should have access to the hall without annoying classes which are in session. Anecdotal remarks reveal that quite a few offices have classrooms as their access passageway. As a result classes must become accustomed to constant interruptions or the office (and often associated prep rooms) will be unused.

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[1] This hypothesis was discussed supra, pp. 35-37, 128-131.

[2] Supra, p. 36.

Hypothesis Fifteen (Sink Size)[1]

The null hypothesis is rejected for this hypothesis; the size of the largest sink is significantly associated with the number of labs[2] in biology and earth science. The association becomes more dramatic, with unknown significance, when only considering teachers having ten to thirteen years of experience. Biology, alone or in conjunction with the previous specifier, also improves the associational value.[3]

One should realize that the size of sinks may be correlated with a third variable having greater significance, or the association found significant in this analysis may indicate even small factors also influence teaching methods.

Hypothesis Sixteen (Optics Exercises)[4]

This hypothesis tries to see if the presence of unavoidable sunlight or hall light is a limiting factor of which physics teachers are aware. A significant association does exist between the inability to darken the room and physics teachers who feel limited in the selection of optical exercises dealing with any phenomenon of light. Factors which lower the associational value are the lack of equipment or use of standard courses not requiring dark rooms. The relationship has a higher associational value when considering physics classes with short periods.

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[1] This hypothesis was discussed supra, pp. 37, 129-132.

[2] Number of labs is expressed in single period equivalents.

[3] See Table Thirty-nine, supra, p. 132.

[4] This hypothesis was discussed supra, pp. 37-38, 133-134.

Hypothesis Seventeen (Undirected Wet Lab)[1]

The main crossbreak did not find a significant relation between the presence of centralized storage and the use of at least one undirected laboratory exercise. When considering only classes having 181-240 minutes per week, a significant relation is found. The absence of centralized storage tends to be significantly associated with teachers not utilizing the undirected technique. The associational value is only moderate, probably because of small cumulative factors not appearing in the crossbreak techniques used in this thesis.

Hypothesis Eighteen and Eighteen Prime (Student Access)[2]

The problem of the effect of after-hour student access on the manner of instruction is over-shadowed by the fear of unsupervised student accidents or misconduct on the part of poorly selected students given the trust of the administration. Extremely few schools permitted even one student to come in and maintain living specimens when just a custodian was in the school. Anecdotal remarks did indicate that in past years, individual projects were stimulated by teachers supervising students late afternoons or on Saturdays. It was the unusual department which maintained supervision until 5:00 P.M. Although extended field trips are currently taken with enthusiasm in some schools, projects are no longer attractive to the vast majority of students.

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[1] This hypothesis was discussed supra, pp. 38-39, 133-135.

[2] This hypothesis was discussed supra, pp. 39-40, 135-137.

The lack of effect on class procedures in science may be a tribute to the organization of teachers. The insignificance of the crossbreaks may also indicate that custodians and teachers are adopting the chores that might be accomplished by students.

Hypothesis Nineteen (Teacher Access)[1]

The effect of after-hour access by teachers to their laboratories was felt more strongly in anecdotal remarks than in the crossbreaks. The main crossbreak failed to reject the null hypothesis concerning a relation between teacher access and lab centered class activity. When only classes having the usual number of periods per week were considered[2], the relationship did become significant. Evidently, a lack of time in class or an abundance of time in class was masking the relationship in the main crossbreak.

Some teachers disliked the responsibility of having keys for the school. Female teachers revealed, in anecdotal remarks, a dislike for deactivating burglar alarms to gain entrance to school. In some cases the inconvenience of obtaining a key or permission for entrance has antagonized laboratory oriented teachers. In rural situations, the ease of getting a key from the principal's home (or department chairman's home) alleviated the need for individual keys.

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[1] This hypothesis was discussed supra, pp. 40, 136-138.

[2] Table Forty-seven, supra, p. 138.

Hypothesis Nineteen Prime (Access-Inquiry)[1]

When teachers who taught a lab centered course were asked if their lab was inquiry oriented, a large number of teachers having after-hour access answered, "no." This had the consequence of making this variation of hypothesis nineteen insignificant. (A smaller percentage of lab oriented teachers without after-hour access answered that they were not inquiry oriented.)

Hypothesis Twenty (Modal Organism)[2]

Because microorganisms were, by far, the predominant organism used in lab, too few replies regarding the use of plants or animals were available for analysis. Anecdotal remarks reveal that all types of organisms seemed to be used with equal enthusiasm.

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[1] This hypothesis was discussed supra, pp. 40, 137-138.

[2] This hypothesis was discussed supra, pp. 41, 139.

CHAPTER VI

APPLICATIONS AND INTERPRETATION

Educational Specifications

Evidence presented by this study might convince some administrators to devote more energy to educational specifications. The translation of these specifications into architectural plans is primarily the duty of the architect.[1] However, it would seem appropriate for educators to supply feedback for architects who feel certain designs embody the intended educational uses of the space and collective aspirations of the institution. Apart from supplying general indications that architectural characteristics might influence teaching, this section attempts to show that data presented in this thesis can be used in translating educational specifications into school plant design.

It must be remembered that failure to reject a null hypothesis proves nothing. Failure to find a significant association does not mean a lack of significant association. Therefore, only the positive results allow conclusions _and_ application. This section will mention only applications derived from significant associations.

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[1] Two national authorities who mention the appropriate limits of educational specifications are cited below.

William Caudell, _Toward Better School Design_ (New York: F.W. Dodge Corp., 1954), p. 28.

W. E. Martin _et al_, "Facilities, Equipment, and Instructional Materials for the Science Program," _Rethinking Science Education_, Fifty-ninth Yearbook of the National Society for the Study of Education, Part I (Chicago: University of Chicago, 1960), p. 233.

As explained earlier[1], the application of this survey's findings serves as a test for the causal interpretation given for the associations found in the data. If architects follow recommendations found here and if the desired influence on teaching is not achieved, then the causal interpretation must be modified. Architects and educational consultants need not ignore data found in this survey because a causal connection has been left untested. This survey presents the best evidence yet given as feedback on architectural influence in science teaching.

Inquiry Teaching

Inquiry teaching can involve both dry and wet laboratory experiences. The modified hypothesis fourteen indicates that for young science departments, giving a teacher his own lab room will enhance the chances of inquiry teaching method.[2] This is only true if one believes that wet lab is a necessary ingredient of the inquiry approach. Put another way, forcing young teachers to share rooms significantly lowers the chances for an inquiry program utilizing at least one wet lab period per week.

A major architectural influence appears to be the separation of the lab space from the classroom.[3] Teachers should be able to conduct laboratory exercises at any time. For the influence of architecture to be felt, a teacher should be assigned to his group of students for all phases of the course. The length of periods may restrict chemistry teachers from utilizing single periods, but biology teachers often can take advantage of even forty minute periods. If wet inquiry teaching is desired, an introductory course with average college preparatory students taught by a teacher having more than one preparation should be held in a classroom-laboratory. This is especially true if the department has not functioned long as a team. The relation also is significant when specification is limited to slightly more mature departments.

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[1] Supra, p. 16.

[2] For supportive data and conclusions for the modified hypothesis fourteen see supra, pp. 35-37, 128-131, 156.

[3] Supra, pp. 26-28, 101-105, 147-149.

The general association of classroom-laboratories with wet inquiry teaching declines when the class of concern is of low or high ability, is a second course, is the only class taught by the teacher, or is given in a school having an exceptionally mature department.

The survey yields some significant data regarding the modal use of wet inquiry methods in biology. It appears that four year high schools are more conducive to wet inquiry methods than are junior high schools.[1] This generalization is only true when speaking of teachers having two preparations per day. Teachers who can handle three or four preparations per day will teach wet inquiry with the same probability in either type school. The heavy-load teachers were often energetic, young, effective teachers. With perimeter storage in junior high schools, there is a possibility that preparation for lab work is more efficient and takes less time than organizing formal lectures. This explanation is peculiar to junior high schools where equipment supplies only one class of advanced ninth graders.

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[1] For supportive rationale, data, and conclusions see supra, pp. 32, 117-118, 152-153.

The presence of only developed (landscaped) land accessible for period length field trips significantly limits the use of the outdoor area for inquiry exercises.[1] The association becomes somewhat more pronounced when a teacher's colleagues in the science department average five to eight years of experience in the same school.[2]

Wet Laboratory Teaching

If a large amount of time is to be devoted to laboratory work, adequate time must be allowed for organizing the laboratory period. For extensive wet laboratory activity, the lack of after-hour teacher self-access to the school becomes an impediment.[3] Anecdotal remarks revealed that arranging for custodians to let teachers in the school or signing out keys for specific access privileges usually does not suffice as an alternative for the issuing of keys to teachers. If security precautions are needed, separate access to science facilities could be designed into the building. The practice of having numerous keys for various stockrooms and cabinets throughout a science department is annoying to most teachers who increasingly find cross-disciplinary needs in equipment and chemicals.

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[1] For supportive data and conclusions see supra, pp. 31, 111-113, 151.

[2] For definition, see X(7), infra, p. 176.

[3] For supportive rationale, data and conclusions see supra, pp. 40, 136-138, 159-160.

Evidently, equipment does make a difference with biology and earth science teachers in regard to the amount of laboratory they conduct. Even among excellent science teachers, improvisation does not mask the effects of an improperly equipped laboratory. The data for hypothesis fifteen[1] shows that there is an association between the size of sinks and the amount of laboratory work done in earth science and, especially, biology. Earth science laboratory takes many forms, including a large amount of map reading. If minerology and model erosional systems are to be subjects of lab work, sink space and large spaces with natural drainage[2] may aid the teacher.

If the desire for undirected wet laboratory exercises appears in the educational specifications, problems may arise with the logistics of complex experiments. Small amounts of time allocated for the class probably prohibits undirected lab work; however, the average time spent in class (including lab work) evidently makes central storage a valuable asset for undirected work.[3] It may be found that the presence of a laboratory assistant and high cost of equipment per lab period, both being associated with centralized storage, are additional factors allowing at least one undirected lab exercise per year.

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[1] Rationale, data and conclusions appear supra, pp. 37, 129-132, 157.

[2] e.g., sand piles.

[3] Rationale, data, and conclusions supporting this statement are found supra, pp. 38-39, 133-135, 158.

Miscellaneous Methods

Use of the library

If training in library research techniques is desired in connection with the science curriculum, the library will more likely be used during class if it is adjacent to the science department.[1] Teachers may tend to give more library instruction when the library is near and when the general student body needs counseling in study technique as indicated by high junior college admissions and low four year college admissions. If the science department budget is high, the influence of the proximity of the library is pronounced.

Use of television

Because broadcast television possesses such large scheduling problems, it was rarely used in the schools visited. Closed circuit television was used more frequently than broadcast television, but overall usage of this expensive equipment was low.[2] Use was highest in the ninth grade and was associated with a high departmental budget.

Showing of films

The convenience of being able to darken a room adequately for showing color films increased the tendency to show films, especially in earth science. Other specifications improving the association were the average student level and extremes in number of double periods per week.[1]

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[1] Rationale, data and conclusions for this statement are presented supra, pp. 25-26, 98-101, 143, 147.

[2] Previous discussion and data on television usage occurs supra, pp. 33, 119, 123, 124, 154.

There seems to be little excuse for poorly operating venetian blinds or high interior windows not being darkenable. Teachers tend to show films even under irritating circumstances; the more films shown, the more annoyance is generated. In general, adequate allowance for cooling a darkened room has not been made. Opening windows with closed venetian blinds often creates distracting rattles and may damage the blinds.

Stimulation of individual projects

The provision of space for individual projects significantly raises the percentage of students engaged in individual laboratory projects.[2] However, individual projects are not as popular, with students, as they were several years ago. The association between project work and individual space increases with the school's stress on college entrance. Low and high ability students take greater advantage of the spaces available and are discouraged in project activity by the lack of space.

If locked individual lab spaces are to be constructed, other aids to individual projects must be planned to insure the use of the spaces which are quite costly. Financial aid for student equipment, resourceful teachers, and after-hour teacher access with possible financial compensation might stimulate better use. Many schools had unlocked space which was not being used. Disinterest on the part of students was the main reason for space not being utilized. Schools might well reconsider their commitments to individual projects before designing spaces for individual projects. Group project work in conjunction with science symposia may attract more gifted pupils to project work than are now being attracted by individual work.

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[1] Rationale, data and conclusions are found supra, pp. 32-33, 119-122, 153. The non-specified test is of doubtful importance.

[2] Rationale, data and conclusions are found supra, pp. 31-32, 113-116, 151-152.

The provision of undeveloped outdoor areas had very low, but significant, association with percent of individual projects done in average level first courses.[1] The implication of this finding may reflect a lack in teacher training for the use of outdoor areas for research.

Lower equipment and supply costs

If the school contains a young science department and enrolls between 751 and 1000 students, higher costs are associated with central science storage. When schools have over 1000 students enrolled, cost of equipment and supplies per lab period is reduced with centralized storage. The management of the storage area may require the hiring of a lab assistant, which may offset the savings in lab expenditures.[2]

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[1] Supra, p. 111.

[2] Rationale, data and conclusions for centralized storage are found supra, pp. 33-34, 123, 126, 154.

Optics experiments

If physics classes are to study optics, physics teachers feel less restricted when they can darken the room. Only one fifth of the physics teachers in rooms having proper darkening ability felt limited by other factors. One half of the teachers in undarkenable rooms felt limited by some factor.[1]

In the design of any science classroom or laboratory, sunlight could be considered a contaminant. The ability to darken a room is advantageous not only for optics, but for experiments in photochemistry, plant physiology, and animal physiology as well as for film showings.

Consequences of Architecture

The findings of this survey need not be interpreted only as a guide for translating educational specifications into architectural realities. One other usage, illustrated here, examines the consequences of architectural practice.

What happens when schools have greenhouses?[2] When limited to the sophomore grade (predominantly biology), there is a slight tendency to use plants experimentally. This is disappointing considering the cost of constructing and maintaining greenhouses. Consideration should be given to large, fluorescently illuminated growth chambers or at least to more expensive greenhouse models with automatic facilities.

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[1] Rationale, data, and conclusions are found supra, pp. 37-38, 133-134, 157-158.

[2] Hypothesis twelve is discussed supra, pp. 34, 125, 127, 154-155.

Summary

The work of the Facilities Research Project has shown that architecture is one of several significant influences on teaching methods used in science instruction. The specific information gained may serve as a guide for decisions to be made in designing new schools. Anecdotal remarks may be of help in pointing out possible improvements in architectural practice; further tabulation of anecdotal remarks remains to be accomplished.

Major findings are enumerated below:

1. Teachers working in classroom-laboratories tend more toward wet inquiry techniques than those using separate laboratory facilities.[1]
2. When the library is adjacent to the science department, a greater proportion of science teachers take or send students to the library during class time.[2]
3. There is a general disuse of outdoor areas, individual project space, and greenhouses.[3] This fact is accounted for by various reasons, some may involve teacher training.
4. Microorganisms are the predominant living organism used in secondary school science, and yet neither teacher training nor design of

---

[1] This is a summary statement of the analysis of hypothesis two.

[2] This is a summary statement of the analysis of hypothesis one.

[3] This statement is based on the analyses of hypotheses five prime, six, seven, and twelve.

laboratories takes this fact into consideration.[1]

5. Under normal circumstances, self-access by teachers to lab facilities is desirable for lab centered classes.[2]

6. There are many situations where advanced ninth graders in junior high schools have less of a chance being taught biology by wet inquiry methods than if they took tenth grade biology. In these cases, the most talented science-oriented students get the least authentic, often boring, science instruction.[3]

A New Area of Research

To some researchers, the design of this study may have seemed loose and unsophisticated. Such critics would argue that the general hypothesis was too broad; control of its study was too problematical. They would argue that, at best, only one specific hypothesis should have been investigated so that all conceivable non-spatial variables could have been taken into account. In fact, some have argued that good research concerning the influence of architecture is not possible with our present state of knowledge about teacher behavior and other relevant variables.

The research presented here has been an attempt to explore a large problem without the complete control desired by other researchers. A new, fertile area of practical concern has been explored. Despite the rather coarse measurement and control, significant results were obtained. Hopefully, others will be stimulated to refine and utilize the rationale and procedures proved useful in this example of educational research concerning architectural space.

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[1] This fact is taken from the data gathered for hypothesis twenty.

[2] See hypothesis nineteen, especially supra, pp. 137-138, 159-160.

[3] This is a summary statement of the analysis of hypothesis eight.

It appears that the investigation of large somewhat nebulous, problems in the natural sciences often has given rise to more research. These subsequent research studies frequently refine the theories originally presented.[1] Possibly educational research strategies could include those proven to be of some worth in other disciplines. What may be needed are some bold hypotheses, challenging fundamental beliefs held by some educators. These hypotheses need not be controlled to the extent that the population to which they pertain or the conclusions reached become insignificant to practitioners. The research presented here attempts to upset the belief that improvisation and teacher training can effectively surmount impediments of inappropriate school design. Until more studies are done, the results of this study assumably pertain to a large geographical region and to all teachers regardless of background or motivation.

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[1] Closely related to the problem of architectural space effects were the problems confronting plant ecologists in the late nineteenth and early twentieth centuries. The ecologists' search was for factors which governed plant distribution. Theories establishing temperature or rainfall as the main determinants were constantly challenged, until today a multiplicity of intricate relations now forms the content of ecology textbooks. The original studies, no matter how over-simplified, were the footholds needed to launch fruitful investigations in plant ecology.

APPENDIX A

THE INTERVIEW SCHEDULE

On the following pages of this appendix, a facsimile of the data gathering instrument appears. Some remarks have been added to the basic form used during interviews; these remarks pertain only to the coding of the information for data processing. Variables often take several columns of an IBM punch card; identification of these variables was made by consecutively numbering each variable. The variable number is indicated by the symbol "X(1...n)" on the facsimile where the answer to the question would normally be placed. Columns one through four contain the identification number of each teacher. Teachers were grouped by school since their first two identification digits are the school's "I.D.#." (Schools were grouped manually by state before punching.) Variable thirty (column fifty-seven, card one) did not have a "0" answer punched; this information could be obtained by using X(19)=3 as a conditional statement. Such an alteration in punching allowed coding of anecdotal information concerning non-laboratory facilities when no lab space was used by the teacher. No other changes have been made in the facsimile.

The hypotheses numbers, located in parentheses after the column number, are keyed to the hypotheses numbers given in Chapter One. These numbers indicate the hypothesis for which the response was used in accordance with suggestions in the thesis proposal.

Following the interview schedule appears a teacher's guide sheet used to aid teachers in understanding my questions for variables thirty-six and forty-four. This guide sheet was the only printed matter shown the teacher during his interview.

School-wide Correspondence Data and Non-spatial I.V.'s

Date______________1967 Mileage________ - ________

Tolls______________ Lodging___________at the___________
____

Meals, etc.__________________________ ____(dates)

Appointments:

Superintendent: Principal: Science Dept. Chairman:

------------------ ----------------------

I.D.#

1. SCHOOL'S NAME______________________ ____ ____
1 2

In key punching, now enter teacher's
I.D. number in cc. 3 and 4

Superintendent's information:

2. System's true real estate valuation per pupil. . . $_ _ _X(1)_ _.00
(based on A.D.M.) 5 6 7 8 9

3. Percentage of graduates going on to accredited colleges

(If information not available, leave blank.) TOTAL. . . . .____X(2)____%
10 11

2 year college: ____X(3)____
12 13

4 year colleges: ____X(4)____
14 15

4. Is it a three year high school?
Yes No

4'. Is ninth grade biology offered in jr. high? Yes No

5. Abnormal year of construction:______ 6. Principal's address

Principal's information:

7. High school enrollment (grades covered:) ____,____X(5)____ ____
16 17 18 19

8. If 4' is yes, below are schools and principals to contact:
Name of school Name of principal

9. Size of school-within-school. . . . . not punched
key: blank = no such organization 20

10. Number of science teachers, grades 10-12.__________

Library notes:

Facilities Research Project School-wide Data and Nonspatial I.V.'s

SCHOOL:____________________N.H.; Mass.; Conn.; N.Y.; N.J.

Science department chairman:

1. Does the science department have a definite budget for each year? yes no

2. What have your science department expenditures, or preferably budgets, been for the last seven years (or less if your school is not that old)? DO NOT INCLUDE COST OF TEXTBOOKS NOR RENOVATION EXPENSES. Lab book purchases may be included if not purchased as a package with the text. If a new policy has been instituted regarding your budget during the years 1960-1966, AND IF THIS POLICY HAS INFLUENCED YOUR PROGRAM, only state the budget for the years under this new program. (We are interested in estimating the cost of various laboratory programs in conjunction with certain aspects of design. We are essentially asking for the cost of equipment and materials.)

'60-61 or 1960_____
'61-62 or 1961_____
'62-63 or 1962_____
'63-64 or 1963_____
'64-65 or 1964_____
'65-66 or 1965_____
'66-67 or 1966_____
(Use school or calender year consistently.)

* * * * * * * * * * * *

X(6)
____ ____ ____ ____
21 22 23 24

Above spaces which are numbered are for key punching average budget.

* * * * * * * * * * * *

3. What is the mean number of years that you and your teachers have been in your science department? Count the time that other teachers may have served before you came to this particular school. If the department existed before moving to this school, count time spent in the old school.

X(7)
____ ____
ten's units
25 26

3'. What is the maximum number of years one could have belonged to the department? (Answer only if your department has been created within the last 7 years.)________

4. Please estimate the number of periods devoted to lab work per week in your science department. State the number in single period equivalents, that is double periods should be counted as two lab periods. If it is easier to state the total number of labs per year, please do so.

__________single periods of lab/week   year

5. How many weeks are available in the school year for laboratory work? Do not count examination weeks, and combine weeks with few days to an equivalent of a four or five day week.

________weeks

6. TABULATOR: Cost per lab (Hypothesis 11). . . . ___X(8)___ ___
27 28 29

7. Length of a single period (in minutes). . . . ______X(9)______
ten's units
30 31

8. Is there central storage for chemicals and apparatus? Yes No

Is such storage departmental? n/a Yes No

(For example, does biology use chemistry's stockroom for biological chemicals?)

Teacher Data Sheet (Non-spatial I.V.'s)

Teacher____________________ School____________________________

Date________________ State N.H., MASS., CONN., N.Y., N.J.

1. How many years have you been in this system? X(10) ten's 32 units 33

2. Subjects now being taught by you:

KEY:

Grade:
1 = 9 11 = 3
2 = 10 12 = 4

Level:
High = 1
Ave. = 2 (college)
Low = 3
Mixed = 4
A.P. = 5 (all high)
second = 6 (all high)
second = 7 (average)

Subject:
Earth Science = 1
General Science = 2
Physical Science = 3
Biology = 4
Chemistry = 5
Physics = 6
Integrated = 7
Anat. & Physio. = 8
________ = 9

List in long hand: (Give relative importance by number of classes or students in parentheses.)

ESTABLISH WHICH ONE IS BEING USED AS THE RESPONSE SET:

Subject: X(11) 34

Grade: X(12) 35

Level: X(13) 36

Years experience with subject: X(14) ten's 37 units 38

3. For above course, what is the
   a. number of single periods per week (2 mods)? X(15) 39
   b. number of double periods per week (3-4 mods)? X(16) 40

4. Number of preparations per day X(17) 41

5. Room number(s)______________(remarks on back)

6. Report request: (check)____

FACILITIES RESEARCH PROJECT

Instructions:

1. When answering, consider the subject stated on the previous page. All answers should pertain to this year's teaching, but you may make comments on other years if you wish.

2. Circle the numerical designator for the teacher's choice.

SPATIAL FACTOR ASSESSMENT

Column # (Hypo #):

X(18) 42(1) If students are going from your classroom(s) to the library, must they pass through another department or do they only go through science department corridors? (Corridors having no classrooms adjacent will be counted as science department corridors since there is no chance of annoying other teachers.)

1 direct access

2 must go through another department

X(19) 43(2) Do you teach in a combination classroom-laboratory or in separate classroom and laboratory facilities? Classrooms with only a demonstration desk do not count as class-labs. Counters or desks must have at least one service to count as a lab bench. The presence of a lab bench defines a laboratory.

1 separate facilities (classroom can have dem. desk)

2 classroom-laboratory

3 classroom only, no lab facilities although there may be a demonstration desk.

(Interviewer: Is demonstration desk the only lab bench?) yes no

X(20) 44(3) Do you teach a class of more than 50 students at one time? Do not include large group instruction sessions that are the lecture portion of team teaching.

1 no

2 yes, regularly

3 yes, infrequently

What is your range of class size?_______ - _______

What is the average size of your discussion class? _______

X(21) 45(4)

______46

______47

When you have a laboratory, what average number of students do you have in your room?

100's	10's	units
45	46	47

X(22) 48(5)

Does your school have an outdoor area or facilities for field work in science?

1 yes

2 no

3 only room for large experiments or meteorological equipment-area may be athletic field or paved.

Type of area: (e.g. habitat)

X(23) 49(6)
(5')

Answer only if answer to above was "yes" (1).

If you have an outdoor instructional area, is it developed beyond the provision for paths and walking surfaces in wet areas? (If trees are labeled, specimens are planted, the ground landscaped, etc., then the area is termed "developed.")

0 teacher says, "ask the biology teachers" (enter 1 or 2 also)

1 developed

2 undeveloped

3 both (to be punched as 2)

X(24) 50(7)

Is space provided for maintaining experimental setups resulting from individual study? Enter yes if some individual work has been done and there seems to be no overload on even small facilities.

1 yes

2 no

X(25) 51

______52

How many students can carry on such projects inside the school at any one time - use space connected with your class area for the answer? Would this answer conflict with another teacher's use of the area? Y N (Departmental facilities are to be included if the teacher feels free to use such facilities.)

X(26) 53(9)

Is your classroom equipped for subdued light during the showing of films? Can you show a color film well?

1 yes, room can be darkened

2 yes, but poor conditions - many light leaks

3 no, room cannot be darkened

Classroom-lab?________ Is this true of the laboratory in separate facility spaces? Y N

N: 1 2 3

X(27) 54(10) Does your school have facilities for allowing closed circuit T.V., T.V. broadcast receiving only, or no television?

1 closed circuit T.V. (not a microprojector) (possibly broadcast too)

2 broadcast only

3 no television

X(28) 55(11) (17) Is common apparatus or are chemicals used by more than one subject stored centrally in one or two storage rooms?

1 yes 2 no 3 n/a, too few rooms

X(29) 56 Are supplies stored centrally for each subject?

1 yes 2 no

X(30) 57(14) Do you have a lab facility? (If no, answer 0. Punch operator ignores zero answer and enters answer for non-lab space. Use X(19)< 3 as condition term for hypothesis fourteen.

Is the lab facility in which you hold your lab exercises FOR YOUR CLASSES' USE ALONE?

1 yes (Homeroom may meet there under other teacher.)

2 yes, but I teach antagonistic subjects there

3 no, but it is oversized to permit each teacher to have his own area

4 no

If the answer is 4, are the other classes science classes? yes no

Is this a classroom-lab about which you speak? Y N

If you teach in separate facilities, do you have your own classroom with free periods in it and no other classes using it?

yes no

X(31) 58(18) (18') Do at least some students have after-hour access to lab facilities when teachers may not be around, e.g. evenings, school year vacations (not necessarily also summer), and weekends?

1 yes

2 no

X(32) 59 Do you have a late bus? 1 yes 2 no When?____

To what time can students stay after school?__________

X(33) 60(19) (19') Do you have self-access to lab and science department office facilities on weekends, evenings and school year vacations (what happens in summer is of no concern)?

1 yes

2 no, but I can make arrangements for the janitor to let me in except on Sundays and legal holidays.

3 no

X(34) 61 Can you have access during the summer vacation period, or at least two weeks before the start of the school year?

1 yes 2 no

X(35) 62 Do you only hold laboratory during double periods?

1 no or I have only single periods

2 yes

X(36) 63(20) Do you use any organisms at all in your class work? If no, answer 4 and ask no more.

Indicate the organism you use most in your laboratory work.

1 microorganisms, including algae and microscopic invertebrates

2 plants, non-microscopic

3 animals, non-microscopic

4 no organisms are used at all

0 use all with equal frequency (only use this choice after considerable probing)

DO NOT COUNT PRESERVED SPECIMENS FOR TABULATED ANS.

____________,

IF preserved specimens were included.

If probing needed, ask what organism they would like to use if they had only one type to choose?

Parts of organisms count. Indicate special sources such as farms, slaughter houses, etc.

X(37) 64(13) BIOLOGY AND EARTH SCIENCE ONLY

Do you have a movable, commercial growth chamber for growing plants under fluorescent light?

1 yes

2 yes, and also a bank of fluorescent lights in an interior room

3 no, but we have a homemade apparatus to replace sunlit vivarium.

4 no

X(38) 65(12) BIOLOGY AND EARTH SCIENCE ONLY

Is there a greenhouse in your department?

1 yes

2 no

X(39) 66(15) BIOLOGY AND EARTH SCIENCE ONLY

Do you have at least one sink in your laboratory room? If not, answer 1 and ask no more.

If you do, is the sink which is biggest of all in the room

2 less than 9 inches on one side?

3 medium in size?

4 larger than 18 inches on one side and roughly square?

5 about 2 feet by 3 feet?

Take measurements if possible:

ROOM #

X(40) 67(8) ONLY NINTH GRADE BIOLOGY

Do you teach ninth grade biology in a

1 junior high school?

2 four year or six year high school?

X(41) 68(16) PHYSICS, PHYSICAL AND GENERAL SCIENCE ONLY (chemistry if teacher brings up subject)

Can you darken your laboratory area (or classroom if no laboratory) sufficiently for experiments with light?

1 yes

2 a room is generally available

3 no

Thank you for answering these questions on your facilities. These replies have pertained to:

subject: room:

Are rooms with other facilities available for your use without much prior arrangement? Y N Is your school, or at least science department generally filled to capacity? Y N

1 80 Card number

INSTRUCTIONAL METHOD ASSESSMENT

Tabulation on second card. Space left for 45 non-spatial I.V.'s

Column #

(hypo #)

X(42) 46(1) Do you give specific instruction in library usage and/or often give class time to students for visiting the library?

1 yes

2 no

(48—1-5) Answer the first four questions and then summarize your predominant type of teaching activity in the fifth question.

(Interviewer: Place the teacher's modal activity in the proper category for the fifth question. The fifth question is the only one used for analysis. If the answers to the first four questions do not clearly indicate the appropriate category, then probe more deeply with specific situations regarding questions 48-2 and 48-3. Have the teacher make a forced decision in the fifth question if he cannot decide.)

X(43) 47
(48-1) Do you give students laboratory activities with actual materials about one single period (double mod) per week or one double period per two weeks OR MORE and/or do you have a BSCS Lab Block or similar solid block of laboratory work for at least 10 days during the year?

1 yes

2 no

Comments (if any) on type of lab block:

(48-2) Do you usually talk about concepts before students are introduced to illustrative phenomena in the laboratory? Do you give the students an idea of what to expect in their laboratory exercise or experiment, other than warning them about hazardous operations or cautioning them about certain observations? Disregard how some fast or slow students might counteract your tactics. IF PHYSICS IS TAUGHT BY MATHEMATICAL DEDUCTION, answer "no" or 1.

1 no

2 yes

0 n/a There is no correlation between lab and lecture.

(48-3) Do you usually wait until after the laboratory to state a generalization or mathematical formula reflecting the phenomenon studied in the laboratory? Hints given to prevent demoralization are allowed under a "yes."

1 yes

2 no

(48-4) If you find the class behind schedule, do you usually quicken the pace to cover material (especially at the end of a semester or year) OR do you usually eliminate some topics that would have been covered under other circumstances?

1 eliminate topics (Even if those eliminated were covered in an earlier year, this answer is still appropriate)

2 quicken the pace, possibly eliminating some lengthy labs. (Lecture style is adopted more; after-school labs may take place of regular labs on optional basis)

—Interviewer: Sum the 1 responses and 2 responses

1 R=__________ 2 R=__________

X(44) 48(2) (8) (48-5) With which statement do you agree?

1. In summary, my class usually centers around a "wet" laboratory in which students practice being scientists or are at least trying to experience activities of scientists. They are involved in inquiry or enquiry. (This statement should agree with the "1" answers for 48-1; 48-2; 48-3; 48-4)
2. My class usually centers around basic scientific concepts which the laboratory will reinforce in understanding and memory. I have a definite list of topics that I value as important (or practical) information to be learned by the student. (This statement should agree with "2" answers in the 48 series).
3. After considerable probing, it was impossible to get teacher to make a choice. The course may be split at mid-year to reverse the philosophy of the course. A small number of important topics can be approached inductively with slow students, essentially eliminating any conflict for time between the product-inquiry approaches.

X(45) 49(3) For this question, answer only in regard to your classes having over 50 students when you have any such classes. Those teachers never having any classes over 50 students will also answer this question.

Does another teacher meet with you and your class for most days and/or always during a lab. DO NOT COUNT OBSERVERS.

1 no (I have a solitary assignment.)

2 yes

(Interviewer: Just during class?______Just during lab?______ Both?______

X(46) 50(4) During laboratory, do you mostly use the class as a research team, each subdivision of the class investigating an aspect of the problem or contributing data for the final write-up to be done by each student or group?

1 yes (team research)

2 no (solitary unit research)

50'(4) verifying question

Do you mostly leave the accomplishment of a lab exercise to each individual student or autonomous team?

1 no

2 yes

(Interviewer: If the numeral of this question does not match with the last question's answer, there is inconsistency. Probe for misunderstanding.)

X(47) 51(5)
(7)
______52
______53

What percentage of your students are doing individual lab projects at some time during the year? (Give the cumulative percentage for the entire school year.)

This may include home projects known to teacher.

100's	ten's	units
51	52	53

X(48) 54(6)

Do you ever use outdoor facilities for genuine problem-solving (inquiry) studies where students cannot find an answer to their specific problem without working in the field OR do you always use outdoor facilities for nature study identification trips and for verifying phenomena discussed in class?

1 problem-solving inquiry
2 verifying nature study
3 not used at all
4 not used and not relevant in opinion of the teacher.

X(49) 55(9)
______56
______57

How many films do you show per year? (If several small films are shown in the same period, count as one film.) Count films shown in the classroom and in the lab. Slides and film strips do not count.

100's	ten's	units
55	56	57

X(50) 58(10)

For this current year, on the average how often did you use television in your class during a ten week period? Study hall use also counts. (If over nine, enter exact number in margin and enter nine as the answer.)[1]

______
58

---

[1] Only two teachers indicated nine or more as an answer. This limitation of nine as a maximum was necessary because of a typographical error in column numbers.

X(51) 59(13)
(20)
Do you or your students usually conduct the laboratory phase of your course by giving quantitative demonstrations instead of, or in addition to, having all students do their own work during lab? For instance, Schwab's Invitations to Inquiry, TOPS or other simulated lab work can serve as a contact with experimentation for the student. Talking about the rationale of historical experiments also counts as a "dry lab" or the type of exercises described above.

1 yes, usual contact with experimental method is by "dry labs"

2 no, usually all students do exercises or experiments in a "wet lab"

3 my students have no lab

4 time spent in quantitative demonstrations and in lab is equal.

Interviewer: In case of difference between levels, indicate--------

Level	Answer
______	______
______	______

(Interviewer: Answer above question in respect to plants IF YOU ARE A BIOLOGY TEACHER. 1 2 3 4

Do you have a growth chamber? Manufactured Homemade None)

X(52) 60(14)
(20)
In your class and lab, is your approach usually to tell a general principle or formula and then to give proof that the principle is true?

1 No, students are usually asked to come up with the general principle by inference from examples, laboratory work, or simulated lab.

2 Yes, I use the lab and examples to verify what the students learn. The lab may be hard to fake, but the general principle is known.

X(53) 61(17)
Do most of your students have at least one real undirected laboratory experience per year? If the student follows instructions from a lab manual or project book, do not count such a lab as undirected. Following instructions for part of the experiment is acceptable only if they are technical preparatory

instructions.

1 yes

2 no

(Interviewer: If the above answer was "1" or yes, find out if most of the class has at least one undirected inquiry laboratory experience per year? Y N)

X(54) 62(18)
(19)
Do you spend at least one-half of the student's time preparing for, doing, or summarizing labs which entail working with actual materials and phenomena? For a class which meets three times per week, at least one lab must be held per week in order to qualify for "1."

1 yes

2 no

If the above answer is no, then the next question must be "no," #4.

X(55) 63(18')
(19')
Is most of the above effort connected with verifying at least several of the laws, relationships, or formulae previously discussed in class?

(REVERSE ORDER FROM TRIAL)

1 yes

2 no

3 lab is not correlated

4 not applicable "no"

X(56) 64(15)
______65
EARTH SCIENCE AND BIOLOGY TEACHERS ONLY
How many single lab periods (or equivalent) do you hold on the average per four week interval? COUNT ONLY WET LABS, where all students work with the materials of your science. Give number of periods per class.

______	______
10's	units
64	65

(12) Do you use living organisms? If no, do not proceed to this Q.

X(57) 66(12) Is there a greenhouse available? Y N

Do you use plants for experimental purposes?

1 yes (controlled)

2 no (demonstration)

3 no, not used

Is your usual use of plants experimental? Y N

Are you using the greenhouse now? Y N

Interviewer: greenhouse survey

	PRESENTLY:	WHEN TEACHER USES IT:
a. experiment going on	__________	__________
b. used for supply	__________	__________
c. supplying plants for experiments done elsewhere	__________	__________

_X(58)_ 67(16) PHYSICS AND PHYSICAL SCIENCE (GEN. SCI.) ONLY

Do you feel limited in the number and type of optical experiments you can perform under existing conditions?

1 yes

2 no

68, 69, 70, 71. Enter number of labs per year in school's science dept.

______ 68 ______ 69 __X(59)__ 70 ______ units 71

Classes:
A
B
C
D
E

Labs/week, year for teacher -- ALL SUBJECTS INCLUDED

__2__ 80 Card Number

Facilities Research Project--FRP

TEACHER'S GUIDE SHEET FOR QUESTIONS 63 and 2-48

63. When first answering, do not include preserved specimens. Then give the answer if these specimens were included.

Indicate the organisms you use most in your laboratory work:

1 microorganisms, including algae and microscopic invertebrates

2 plants, non-microscopic

3 animals, non-microscopic

4 no organisms are used at all

2-48 With which statement do you agree?[1]

Statement 1: In summary, my class usually centers around "wet" laboratory in which students practice being scientists or are at least trying to experience activities of scientists. They are involved in inquiry or enquiry.

Statement 2: My class usually centers around basic scientific concepts which the laboratory will reinforce in understanding and memory. I have a list of topics that I value as important (or practical) information to be learned by the student.

---

[1] Many teachers said that they did not agree with what they were doing in principle, but they did feel one of these statements did typify their class.

APPENDIX B

VARIABLE LIST AND DEFINITIONS

This appendix presents a list of non-spatial, spatial, and methodological variables keyed to the X(1...n) data fields given in Appendix A.

Non-spatial Independent Variables

Years subject experience, X(14):

VAR(1) = X(14)

VAR(2) = redefined X(14) = (1 = First/ 2,3 = New/ 4-5 = Young Tenure/ 6-9 = II-Tenure/ 10-13 = III-Tenure/ 14-21 = IV-Tenure/ others = V-Tenure)

Average departmental budget (in tens of dollars), X(6):

VAR(3) = X(6)

VAR(4) = redefined X(6) = (0-2,990 = I/ 3,000-5,990 = II/ 6,000-9,990 = III/ 10,000-15,750 = IV/ 15,760-21,500 = V)

VAR(5) = redefined X(6) = (0-4,540 = Low/ 4,550-21,500 = High)

Cost per laboratory[1], X(8)

Budget per pupil, X(6) / X(5):

VAR(9) = X(6) / X(5)

VAR(128) = redefined VAR(9) = (Under 0.376 = Low/ Others = High)

---

[1] VAR(6,7,8) are listed at the end of the dependent variable section, infra p. 203.

Percentage going to college, X(2):

VAR(10) = X(2)

VAR(11) = redefined X(2) = (1-42% = Low/ 43-76% = Average/ 77-100% = High)

VAR(12) = redefined X(2) = (1-59% = Lower/ 60-100% = Higher)

Percentage going to junior college only, X(3):

VAR(13) = X(3)

VAR(14) = redefined X(3) = (1-10 = Lower/ 11-16 = Average/ 17-44 = High)

VAR(15) = redefined X(3) = (1-13 Lower/ 14-99 = Higher)

School enrollment, X(5):

VAR(16) = X(5)

VAR(17) = redefined X(5) = (226-750 = I/ 751-1000 = II/ 1001-1250 = III/ 1251-1500 = IV/ 1501-2250 = V/ 2251-3000 = VI)

VAR(18) = redefined X(5) = (0-750 = I/ 751-1500 = II/ 1501-2250 = III/ 2251-3000 = IV)

VAR(19) = redefined X(5) = (0-750 = I/ 751-3000 = II)

VAR(20) = redefined X(5) = (0-1435 = Lower/ 1436-3000 = Higher)

Mean years in science department, X(7):

VAR(21) = X(7)

VAR(22) = redefined X(7) = (0-4 = Young average/ 5-8 = Old average/ 9-17 = Old)

VAR(127) = redefined X(7) = (1-4 = Young average/ 5-7 = Old average/ 8-17 = Old department)

Single period length in minutes, X(9):

VAR(23) = X(9)

VAR(24) = redefined X(9) = (20-39 = Short/ 40-49 = Short Average/
50-59 = Long average/ 60 = Long)

VAR(25) = redefined X(9) = (20-49 = Shorter/ 50-60 = Longer)

VAR(26) = redefined X(9) = (20-46 = Shorter/ 47-60 = Longer)

Double periods per week, X(16):

VAR(27) = X(16)

VAR(28) = redefined X(16) = (0 = None/ 1 = One/ 2 = Two/ 3 = Three/
4-5 = Four or Five)

VAR(29) = redefined X(16) = (0 = None/ 1 = One/ 2 = Two/ 3-5 = Over two)

Single periods per week, X(15):

VAR(30) = X(15)

VAR(31) = redefined X(15) = (0-1 = Few/ 2-3 = Moderate/ 4-5 = Modal/
6-7 = Heavy)

Double period time, X(16) x 2 x X(9):

VAR(32) = X(16) x 2 x X(9)

VAR(33) = redefined VAR(32) = (0 = None/ 40-60 = I/ 61-120 = II/
121-240 = III/ 241-400 = IV/ 401-600 = V)

VAR(130) = redefined VAR(32) = (0 = None/ 40-120 = 40-120/ 121-240 =
121-240/ 241-600 = 241-600)

VAR(131) = redefined VAR(32) = (0 = None/ 40-180 = 40-180/ 181-600 =
Over 3 hours)

Weekly student time, (X(16) x 2 x X(9)) + (X(15) x X(9)):

VAR(34) = (X(16) x 2 x X(9)) + (X(15) x X(9))

VAR(35) = redefined VAR(34) = (61-180 = I/ 181-240 = II/ 241-300 =
III/ 301-360 = IV/ 361-540 = V)

Preparations per day, X(17):

VAR(36) = X(17)

VAR(37) = redefined X(17) = (1 = 1/ 2 = 2/ 3 = 3/ 4-5 = High)

VAR(38) = redefined X(17) = (1 = One/ 2 = Two/ 3-5 = Heavy)

VAR(39) = redefined X(17) = (1 = Only one/ 2-5 = Over one)

Level of course, X(13):

VAR(135) = X(13) = (1 = High first course/ 2 = Average first course/ 3 = Low first course/ 4 = Mixed first course/ 5 = Advanced Placement/ 6 = High second course/ 7 = Average second course)

First course level, X(13):

VAR(40) = redefined X(13) = (1 = High/ 2 = Average/ 3 = Low)

Second course level, X(13):

VAR(41) = redefined X(13) = (5 = A.P./ 6 = 2nd High/ 7 = 2nd Ave.)

Grade, X(12):

VAR(42) = X(12) = (1,9 = FROSH/ 2 = SOPH/ 3 = JUNIOR/ 4 = SENIOR)[a]

Course subject, X(11):

VAR(43) = X(11) = (1 = Earth Science/ 2 = General Science/3 = Physical Science/ 4 = Biology/ 5 = Chemistry/ 6 = Physics/ 7 = Integrated/ 8 = Anatomy and Physiology-Human)

Number of single periods when no double periods, X(15) modified:

VAR(44) = X(15) IF X(16) EQUALS 0

---

[a] The classification of one response as nine showed in the frequency analysis. This is presumably a coding error.

VAR(45) = redefined VAR(44) = (4 = Four/ 5 = Five/ 6 = Six/ 7 = Seven)
(others disregarded)

Any other non-spatial information collected was not used for analysis in this thesis but was saved for future Project work.

Spatial Independent Variables

Direct access to library, X(18):

VAR(46) = X(18) = (1 = Direct/ 2 = Indirect)

Classroom -- laboratory arrangement, X(19):

VAR(47) = X(19) = (1 = Separate/ 2 = Classroom-laboratory)

Class size more than 50 students, X(20):

Infrequently large:

VAR(48) = redefined X(20) = (1 = No/ 2,3 = Yes)

Usually large:

VAR(49) = redefined X(20) = (1,3 = No/ 2 = Yes)

Average number of students in laboratory, X(21):

VAR(50) = X(21)

VAR(51) = redefined X(21) = (0-10 = 0-10/ 11-20 = 11-20/ 21-24 = 21-24/
OVER 24 = Over 24)

VAR(52) = redefined X(21) = (0-24 = 0-24/ OVER 24 = Over 24)

Availability of an outdoor area, X(22):

VAR(53) = X(22) = (1 = Yes/ 2 = No)

Type of outdoor area available, X(23):

VAR(54) = redefined X(23) = (1 = Developed/ 2,3 = Undeveloped)

Individual laboratory space available, X(24):

VAR(55) = X(24) = (1 = Available/ 2 = Not available)

Anecdotal record:

VAR(56) = X(25) = Number accommodated in individual laboratory space.

Room darkenable for color films, X(26):

VAR(57) = X(26) = (1 = Yes/ 2 = Poorly/ 3 = No)

VAR(140) = redefined X(26) = (1 = Yes, excellent/ 3 = No)

Type of television, if any, available, X(27):

VAR(58) = redefined X(27) = (1 = Closed circuit/ 2 = Broadcast receiving only)

Central storage of supplies, X(28):

VAR(59) = X(28) = (1 = Yes/ 2 = No)

Anecdotal record:

VAR(60) = X(29) = Subject area storage (1 = Yes/ 2 = No)

Teacher has own room, X(30):

VAR(61) = redefined X(30) = (1,2 = Yes/ 3,4 = No)

Teacher has own laboratory, X(30):

VAR(62) = VAR(61) IF X(19) LESS THAN 3 = (1,2 = Yes/ 3,4 = No)

Anecdotal record:

VAR(63) = VAR(61) IF X(19) EQUALS 2 = Teacher has own classroom-lab (1,2 = Yes/ 3,4 = No)

Students' after hour access, X(31):

VAR(64) = X(31) = (1 = Yes/ 2 = No)

Anecdotal record:

VAR(65) = X(32) = Late bus available = (1 = Yes/ 2 = No)

Teachers have after hour access, X(33):

VAR(66) = redefined X(33) = (1 = Yes, on own/ 3 = No)

VAR(67) = X(33) = (1 = Yes, on own/ 2 = Must be let in-inconvenient/ 3 = No)

Anecdotal record:

VAR(68) = X(34) = Teacher can get in during summer vacation at least two weeks before school formally opens = (1 = Yes/ 2 = No)

Laboratory held only during double periods, X(35):

VAR(69) = X(35) = (1 = No, lab is held during singles/ 2 = Yes, only during doubles)

VAR(70) = redefined X(35) = For those who have double lab periods, do they use only the double period? (1 = No/ 2 = Yes) = X(35) IF X(16) GREATER THAN 0

Predominant living organism used in lab, X(36):

VAR(71) = X(36) = (1 = Microorganisms/ 2 = Plants/ 3 = Animals/ 4 = No living organisms, except students) See actual question for better definitions.

Commercial growth chamber available, X(37):

VAR(72) = redefined X(37) = (1 = Yes/ 4 = No)

VAR(73) = redefined X(37) = (1,2 = Yes/ 3,4 = No)

VAR(74) = redefined X(37) = 1,2,3 = Yes/ 4 = No)
See actual questions to see difference in situations 1,2,3, and 4.

Greenhouse available for use, X(38):

VAR(75) = X(38) = (1 = Yes/ 2 = No)

Size of sink in biology or earth science rooms, X(39):

VAR(76) = X(39) = (1 = None/ 2 = Small/ 3 = Medium/ 4 = Large/ 5 = Extra large), see question for measurements and the analysis section for slight revisions in category definitions.

VAR(138) = X(39) = (2 = Small/ 3 = Medium/ 4 = Large/ 5 = Extra Large)

Type of school in which biology is taught, X (40):

VAR(77) = X(40) = (1 = Junior high school/ 2 = Four or six year high school)

Room can be darkened sufficiently for experiments with light, X(41):

VAR(78) = X(41) = (1 = Yes/ 2 = another room is available/ 3 = No)

VAR(139) = redefined X(41) = (1 = Yes/ 3 = No)

Methodological Dependent Variables

Library instruction is given, X(42):

VAR(79) = X(42) = (1 = Yes/ 2 = No)

At least one period of wet lab per week, X(43):

VAR(80) = X(43) = (1 = Yes/ 2 = No)

Course is generally inquiry-wet or verifying-wet or -dry, X(44):

For all teachers:

VAR(81) = redefined X(44) = (1 = Inquiry wet/ 2 = Verifying)

For teachers averaging at least one lab per week:

VAR(119) = VAR(81) IF X(43) EQUALS 1

Another teacher usually meets with class at same time X(45):

VAR(82) = X(45) = (1 = No, solitary/ 2 = Yes, cooperative)

Team research organization in class - modal, X(46):

VAR(83) = X(46) = (1 = Team/ 2 = Solitary)

Percent of individual projects, cumulative for year, X(47):

VAR(84) = X(47)

VAR(85) = redefined X(47) = (0 = None/ 1 = 1%/ 2-9 = Few/ 10-20 = Ten-Twenty/ 21-90 = Heavy/ 91-100 = Compulsory)

VAR(86) = redefined X(47) = (0 = None/ 1-3 = Few, if any/ 4-20 = 4-20/ 21-90 = 21-90/ 91-100 = 91-100)

VAR(87) = redefined X(47) = (0 = None/ 1-3 = Few, if any/ 4-90 = Several/ 91-100 = Compulsory)

VAR(88) = redefined X(47) = (0 = None/ 1-100 = Some)

VAR(89) = redefined X(47) = (0 = None/ 1-99 = Some)

VAR(126) = redefined X(47) = (0 = None/ 1-5 = 1-5/ 6-10 = 6-10/ 11-30 = 11-30/ 31-59 = 31-59/ 60-90 = 60-90/ 91-100 = 91-100)

VAR(132) = redefined X(47) = (0-20 = Lower/ 21-100 = Higher)

VAR(133) = redefined X(47) = (0-3 = Few, if any/ 4-90 = Some--high)

VAR(134) = redefined X(47) = (0-3 = Few, if any/ 4-90 = Some/ 91-100 = Compulsory)

Outdoor facilities used for inquiry, X(48):

VAR(90) = redefined X(48) = (1 = Yes/ 2,3 = No)

VAR(91) = redefined X(48) = (1 = Inquiry/ 2 = Verifying)

Outdoor use, X(48) modified:

VAR(92) = redefined X(48) = (1,2 = Used/ 3 = Not used/ 4 = Not relevant)

VAR(93) = redefined X(48) = (1,2 = Used/ 3 = Not used)

Films shown per year, X(49):

VAR(94) = X(49) (normally distributed)

VAR(95) = redefined X(49) = (0 = None/ 1-5 = 1-5/ 6-10 = 6-10/
11-20 = 11-20/ 21-30 = 21-30/ OVER 30 = Over 30)

VAR(96) = redefined X(49) = (0 = None/ 1-10 = 1-10/ 11-38 = 11-38/
OVER 38 = 38+)

VAR(136) = redefined X(49) = (0-15 Below mean/ OVER 15 = Above mean)

VAR(137) = redefined X(49) = (0-12 = Below median/ OVER 12 = Above median)

Television use per class in 10 weeks, X(50):

VAR(97) = X(50)

VAR(98) = redefined X(50) = (0 = Not at all/ 1 = Once or so/ 2-9 =
Some -- much)

VAR(99) = redefined X(50) = (0,1 = None -- once/ 2-3 = Few/ 4-9 =
Regularly)

VAR(100) = redefined X(50) = (0,1 = None - once/ 2-9 = Few -- much)

Dry versus wet lab as modal lab, X(51):

VAR(101) = redefined X(51) = (1 = Demonstration -- dry/ 2 = Wet lab)

VAR(102) = redefined X(51) = (1 = Demonstration -- dry/ 2 = Wet lab/
3 = No lab)

General approach to class, Inductive - Deductive, X(52):

VAR(103) = X(52) = (1 = Inductive/ 2 = Deductive, verifying)

At least one undirected lab per year for most students, X(53):

VAR(104) = X(53) = (1 = At least one/ 2 = None)

One-half of students' time centered around laboratory, X(54):

VAR(105) = X(54) = (1 = Yes/ 2 = No)

If lab centered, then inquiry or verifying? X(55):

VAR(106) = redefined X(55) = (1 = Verifying/ 2 = Inquiry)

VAR(107) = redefined X(55) = (1 = Verifying/ 2 = Inquiry/. 3 = Lab not related to class discussion)

Average number of lab periods per four weeks in biology and earth science, X(56):

VAR(108) = X(56)

VAR(109) = redefined X(56) = (1-2 = Few/ 3-4 = Regular/ 5-10 = High/ OVER 10 = Heavy)

VAR(129) = redefined X(56) = (UNDER 9 = LOW/ 9-24 = HIGH)

Use of Living Plants, X(57):

VAR(112) = X(57)[a]

VAR(110) = redefined X(57) = (1 = Experimental/ 2,3 = Not so)

VAR(111) = redefined X(57) = (1 = Experimental/ 3 = Not used)

VAR(113) = redefined X(57) = (1 = Experimental/ 2 = Anatomical/ 3 = Not used)

Limited in doing experiments with light, X(58):

All relevant courses, including chemistry:

VAR(115) = X(58) = (1 = Limited/ 2 = Not limited)

---

[a] This nominal scale is meaningless without labels; it was included here to fill the array statement for the computer. Number VAR(112) had been skipped during the writing of variable definitions.

Just physics:

VAR(114) = X(58) IF X(11) EQUALS 6 = (1 = Limited/ 2 = Not limited)

Number of lab periods in department per year, X(59):
(N = 59, since this is departmental)

VAR(116) = X(59)

VAR(117) = redefined X(59) = (1-2400 = Lower/ OVER 2400 = Higher)

VAR(118) = X(59)/ 100 = Labs per year in nearest 100.
(Expressed as an integer.)

Cost per laboratory, X(8):

VAR(6) = X(8)

VAR(7) = redefined X(8) = (50-125 = I/ 126-175 = II/ 176-225 = III/
226-275 = IV/ 276-999 = V)

VAR(8) = redefined X(8) = (50-205 = Low/ OVER 205 = High)

APPENDIX C

KINDS OF LETTERS SENT TO ARRANGE INTERVIEWS

The letters included in this appendix represent the general type of letters sent to the superintendents, principals, and department chairmen. Letters varied in the details of arrangements, for instance:

1) to whom the investigator had previously written,

2) date of interview,

3) number of days for interview,

4) type of teachers to be interviewed,

and 5) arrival and departure times.

Five usual kinds of letters were sent during the interview phase. They were

1) the first request of the superintendent,

2) an April 28th reminder letter to eight superintendents not answering the first letter,

3) the principal's request,

4) the letter of arrangements to the department chairman,

and 5) a thank you note to the department chairman and also the principal if the latter met the investigator.

The first four types of letters are exemplified by the letters placed in this appendix.

First Superintendent's Letter

February 1967

Mr. John Doe
Superintendent of Schools
46 Main Street
Good Town, State 00000

Dear Mr. Doe:

The Harvard Graduate School of Education, with the cooperation of an educational consulting firm and several state commissioners of education, has begun a study concerning the influence of school design on science instruction. The Good Town Senior High School has been nominated to be included in this study. We would appreciate your permission to conduct a survey of science facilities and teaching methods in this school. Through visiting schools such as yours, it is hoped that some information can be gained which will aid future school designers in planning more functional and economical facilities for grades nine through twelve.

The survey will be conducted by Mr. David Engelhardt, who will hold an approximately thirty minute individual interview with each science teacher and observe certain aspects of the science facilities. It is anticipated that all high school science teachers and ninth grade biology teachers will be interviewed in one day. In case of three year high schools, the junior highs or middle schools will have their ninth grade biology teacher and facilities visited, in addition to the normal visitation connected with the high school.

In your letter granting permission, would you please include the answers to the following questions:

1) What is your system's true real estate valuation per pupil?

2) What percentage of this high school's graduates go on to accredited junior or four year colleges? If possible, please separately state the percentage going to each type of institution.

3) Is the school a three year high school? If so, is ninth grade biology offered in any of the junior high schools which feed this high school?

4) Is Mr. Simon still the principal of the high school? Please supply the school's address with zip code so that we may

quickly contact the principal for permission to visit.

It is understood that Good Town Senior High School has been built since 1960 (January 1, 1960 earliest occupancy date) or that its science facilities have been substantially remodeled since that date. If this is not the case, please mention the date of construction or remodeling.

Thank you very much for your cooperation. Your prompt consideration of this letter would be most beneficial to us in setting up a visitation schedule through the principal and department chairman. Your reply should be sent to:

Mr. David F. Engelhardt
Facilities Research Project
323 Longfellow Hall-Appian Way
Harvard Graduate School of Education
Cambridge, Massachusetts 02138

Sincerely yours,

David F. Engelhardt
Researcher
Natural Science Dept.

Fletcher G. Watson
Professor of Education

DFE-FGW/ft

Second Superintendent's Letter

April 28, 1967

Mr. John Doe
Superintendent of Schools
46 Main Street
Good Town, State 00000

Dear Mr. Doe:

On February 27, 1967 you were sent a letter requesting permission to include Good Town Senior High School in our Facilities Research Project. As of today, we have no record of your reply. It is possible that we have lost your reply or that the post office has lost our letters; but it may be that our request has been lost in the heavy correspondence load common to many superintendents' offices. Would you please indicate by return mail or a collect phone call whether or not you intend to participate. (Area Code 617, 332-1946 is my home phone, where messages can be left for me.) The final schedules for visits are now being constructed. Because of economical considerations we have delayed visiting other schools that have replied in your area, but we do not wish to wait much longer for your reply since early visits are preferred by most schools. Would you please reply promptly so that only one trip will be necessary to your region.

I will repeat the explanation of the project as presented in our original letter. It would aid us if you would ask the principal of the Good Town Senior High School to answer this letter for both of you at the same time. We will then contact the science department chairman to arrange a convenient visitation date.

The Harvard Graduate School of Education -- with the cooperation of an educational consulting firm, several state commissioners of education, local school administrators, and many teachers -- has been conducting a study concerning the influence of school design on science instruction. It is for this study that I am requesting permission from you and the principal to visit Good Town Senior High School. My visit will involve thirty minute, individual interviews with each science teacher and some after school inspection of the facilities. It is hoped, through visiting schools such as yours, that some information can be gained to aid future school designers in the planning of more functional and economical science facilities for grades nine through twelve.

Would you please supply the information requested below:

1) What is your system's true real estate valuation per pupil?

Mr. John Doe

April 28, 1967

2) What percentage of your graduates go on to accredited junior or four year colleges? If possible, state separately the percentage going to each type of institution.

3) What is the present enrollment of the high school?

4) If the Good Town Senior High School is a three year high school, do you teach ninth grade biology in your school system?

5) How many science teachers do you have for the tenth through twelfth grade subjects?

6) Who is the science department chairman for the high school? Please give the full address of the high school with zip code.

7) Kindly state any periods which should be avoided, including the final exam period.

Your cooperation in this matter is deeply appreciated.

Sincerely yours,

David F. Engelhardt
Researcher
Facilities Research Project

DFE/fc

Principal's Letter

April 1967

Mr. Frank W. Simon, Principal
Good Town Senior High School
School Street
Good Town, State 00000

Dear Mr. Simon:

The Harvard Graduate School of Education -- with the cooperation of an educational consulting firm, several state commissioners of education, and many local school systems -- has begun a study concerning the influence of school design on science instruction in grades nine through twelve. Your superintendent of schools may have mentioned that he has given us permission to approach you for the privilege of including Good Town Senior High School in our survey. It is understood that your school covers no more than four grades; please inform me if this is not the case since the study is generally limited to three and four year high schools.

The survey will be conducted by holding individual thirty minute interviews with each science teacher and by observing certain aspects of the science facilities. After obtaining your permission, I will ask the science department chairman to arrange an interview schedule for a mutually convenient date.

In your letter granting permission to visit your school, would you please supply the following information:

1. What is the present enrollment of your school? (If you have a school-within-a-school organization, please give the size of each "house" or sub-unit.)
2. If ninth grade biology is taught in any junior high school which feeds your school, please send me the name of the school and its principal's name for use in arranging interviews with ninth grade biology teachers.
3. How many science teachers do you have for the tenth through twelfth grade subjects?
4. Who is the science department chairman for the high school?
5. Kindly state any periods which should be avoided because of vacations and also state when final exams start.

Mr. Frank Simon April 1967

Thank you very much for your cooperation. Through visiting such schools as yours, it is hoped that some information can be gained which will aid future school designers to plan more functional and economical science facilities for secondary schools.

Sincerely yours,

David F. Engelhardt
Researcher
Facilities Research Project

DFE/fc

Department Chairman's Letter

May 1967

Mr. Joseph Smith
Science Department Chairman
Good Town Senior High School
School Street
Good Town, State 00000

Dear Mr. Smith:

As your principal has probably told you, your science department has been nominated for inclusion in the Facilities Research Project. The Harvard Graduate School of Education -- with the cooperation of an educational consulting firm, several state commissioners of education, local school administrators, and many teachers -- has begun a study concerning the influence of school design on science instruction. Schools are being visited in an attempt to find if correlations exist between facilities and teaching methods. Would you please confirm that Wednesday, May 24, 1967, is a convenient time for your staff to have me visit your school. If this tentative date is not convenient, please feel free to ask for another time. (A postal card is enclosed for your convenience in replying. If you mail the reply card within a week of the above date, please also phone my home collect, and leave a message which will be phoned to me while I am on the road. My home number is given toward the end of this letter.) In your reply, please give the time I should report to your school.

Let me explain in somewhat more detail what is usually done when I conduct the survey. Science teachers describe their instructional methods and facilities during individual thirty minute interviews with me. Following the interviews, which are usually held during the free periods of the teachers, I often check on certain characteristics of your facilities which were not clear in the interviews.

I would appreciate your setting up an interview schedule for all your science teachers of tenth through twelfth grade subjects and teachers of ninth grade biology. If time permits in the same day, earth science teachers may be interviewed also, regardless of the grade taught. Usually teachers prefer to know a day in advance that their free period will be occupied by an interview. It is hoped that all teachers concerned can be interviewed in one day. Physical science teachers can be interviewed in twenty minutes if need be, whereas biological science teachers take the full thirty minutes. I can be at your school as early as you wish and can stay a few hours after school is dismissed. However, teachers should not be asked to stay after school for me if they are not

-2-

Mr. Joseph Smith May 1967

accustomed to staying late.

Enclosed is a list of questions[1] which I will be discussing only with you. The information requested may require some prior thought. Do not allow much time to be spent answering these questions, since talking with me might save much time that might have been wasted because of misunderstanding.

Mail will reach me more quickly at home; please reply to the following address:

Mr. David Engelhardt
33 Parsons Street
West Newton, Mass. 02165

If a limited time exists for replying or a very serious impediment materializes for the survey, please contact me at any time through my home by calling collect, Area Code 617, 332-1946.

I realize that eleven teachers will tend to fill the day. If, by any quirk of scheduling, there does appear to be enough time to visit the junior high biology teacher, you may feel that it would be proper for you to ask the junior high if I could visit during the time available. If you are not in such a supervisory position, I will make the arrangements myself. It happens that I will be visiting two neighboring communities Monday and Tuesday. Since they are smaller than your school, I may have time to phone you about possibly meeting you after school some time prior to the rushed Wednesday.

Thank you very much for the time you have taken from a busy schedule for cooperating with this project; your active participation is greatly appreciated.

Sincerely yours,

David F. Engelhardt
Researcher
Facilities Research Project

DFE/fc

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[1] The second page of the data sheets, supra pp. 176-177 was enclosed.

APPENDIX D

ANALYSES USED FOR CROSSBREAKS

The tests used for specific hypotheses are discussed briefly in the Data-Text Manual.[1] The general analytical procedure already has been explained.[2] It remains for the formulae and statistical comments to be given in this appendix.

The background of analyses presented here is not intended to be a full presentation of the various tests. Only those tests allowing explanation in a small amount of space will be explained. Any tests not discussed in full are explicated in numerous statistics texts.

For most non-parametric tests, which are the vast majority of tests used in this thesis, the computations are based on the Crosstabs Program of the Data-Text System. Figure Three[3] gives the key to symbols found in statistical formulae presented in this Appendix.

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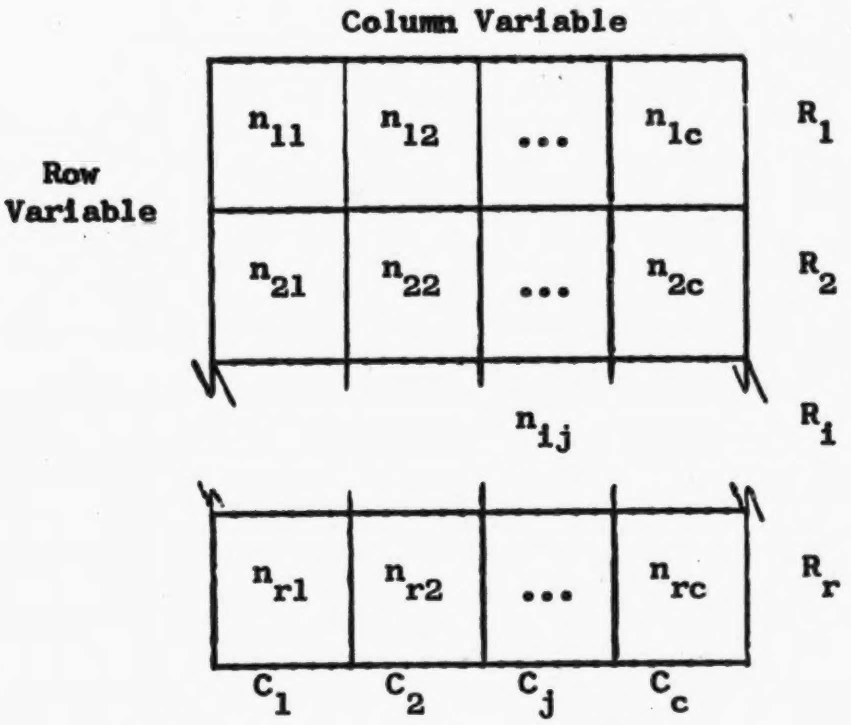
[1] Arthur Couch, pp. 305-334, 349-354, 371-380. Also see supra, p. 54.

[2] Supra, pp. 54-58.

[3] This schematic table is adapted from the Data-Text Manual — Couch, p. 323.


Column Variable
Row Variable
n_{11}
n_{12}
...
n_{1c}
R_1
n_{21}
n_{22}
...
n_{2c}
R_2
n_{ij}
R_i
n_{r1}
n_{r2}
...
n_{rc}
R_r
C_1
C_2
C_j
C_c

n_{ij} = Count in the $(i,j)^{th}$ cell

R_i = Count in the $(i)^{th}$ row

C_j = Count in the $(j)^{th}$ column

r = Number of rows

c = Number of columns

N = Total count of the table

Fig. 3 - Schematic Crosstab Key

Nominal Comparisons

The Data-Text System provided a convenient and rapid method for nominal analysis. Although many variables had ordinal scales, nominal procedures were used at the beginning stages of analysis. Where no significant nominal relations occurred and where there appeared to be a relation, ordinal tests were done by hand. For the vast majority of crossbreaks, the nominal test of significance was an adequate type of non-parametric procedure.

Associational measures were expanded to include ordinal tests, thereby taking full advantage of the information in the data.

Unfortunately there was no way to see if a tau C ordinal measure actually improved the associational measure of Cramér's V.[1] This is one reason why numerous measures of association are given in the crossbreak tables.[2]

When a test of significance for ordinal comparisons was needed, nominal comparisons were often done in preference to the extremely conservative test of tau C significance given by Stuart.[3] The investigator did not have access to Kendall's S statistic which could have been used for significance calculations; the investigator was forced to use a less precise calculation based on the tau C value as reported by the computer.

Tests of Significance

The nominal tests of significance used in this thesis are 1) chi-square, 2) chi-square with Yate's correction for continuity, and 3) Fisher exact test of probability. The option of these tests is taken by the computer according to criteria explained in the Data-Text Manual[1]. The Fisher exact probability test could feasibly be done by computer for certain contingency tables having one extremely low expected score with large expected scores elsewhere. Unfortunately, for the Fisher exact test, the programmer's executed command was not functional at the time of computation. Hand calculation for tables having over forty teachers (usually over one hundred) is much too laborious -- taking at least several days for each table. Hence, only the automatic option for the Fisher exact test was used.

---

[1] Table 22 gives an example of extremely low tau C, G and D measures with a fairly high Cramér's V. The test is reported as the following crossbreak: High First Level (VAR 40) versus VAR(87) versus VAR(55). It is probable that a combination of low ordinal association and high nominal coefficient is due to low expected frequencies.

[2] Including a selection of coefficients will also allow the reader to select the measure with which he has had most experience.

[3] Allan Stuart, "The Estimation and Comparison of Strengths of Association in Contingency Tables," Biometrika, XL(1953), 105-110. This test uses the upper limit estimate of standard error of the tau C statistic to establish confidence intervals.

Chi-square test

The formula, keyed by the Schematic Crosstab in Figure Three, for chi-square is

$$\chi^2 = \sum \sum \frac{(n_{ij} - E_{ij})^2}{E_{ij}}$$

with (r-1) (c-1) degrees of freedom and where

$$E_{ij} = \frac{(R_i)\ (C_j)}{N}\ .^2$$

If less than 20% of the cells have an expected frequency less than five but greater than zero, the chi-square is considered legitimate. This limitation is not made by Data-Text which observes a more liberal criterion.[3]

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[1] Couch, pp. 325-326. These criteria are based on W. G. Cochran, "Some Methods for Strengthening Common χ^2 Tests," Biometrics, X(Dec. 1954), pp. 417-451.

[2] E_{ij} is the expected cell frequency.

[3] Couch, p. 326 uses the Mean and Variable technique which is not discussed in standard references.

Yates chi-square

If the contingency table is two-by-two and if the total count is greater than forty, a Yates's correction for continuity is applied. If a four-fold table count is greater than twenty and less than forty-one, a Yates's correction is done only if all expected cell frequencies are at least five. This correction adds 0.5 to frequencies which are less than expected and subtracts 0.5 from frequencies greater than expected. This corrected chi-square is essentially the same as the uncorrected chi-square with large frequencies.

Fisher exact test

The Fisher exact probability test is used when an expected frequency is lower than five. It gives a one-tailed probability of the null hypothesis being acceptable. This test uses the following formula based on the Figure Three schematic:

$$P_i = \frac{R_1!\ R_2!\ C_1!\ C_2!}{N!\ n_{11}!\ n_{12}!\ n_{21}!\ n_{22}!}$$

The test is only computed for two-by-two tables.

Measures of Association

The nominal measures of association used in the thesis are 1) contingency coefficient, 2) phi coefficient, and 3) Cramér's V coefficient.

Contingency coefficient

The Data-Text program calculates the contingency coefficient from the following formula:

$$C = \sqrt{\frac{\chi^2}{N + \chi^2}}.$$

Ferguson[1] lists the following maximal values for square contingency tables. For tables where rows do not equal columns, the maximal values would be the same as a square table having the smaller number of rows or columns. Part of Ferguson's list is given in Table 50.

TABLE 50

MAXIMAL VALUES FOR C

Number of Categories for Both Variables	Maximal C
2	0.707
3	0.816
4	0.866
5	0.894
6	0.913

Unfortunately, this widely used coefficient is not a sensitive measure of most tables in this thesis, such as a two-by-six table.

Phi coefficient

Although the phi coefficient is identical to the Pearsonian product-moment correlation when marginal frequencies are evenly divided, the phi coefficient is considered a non-parametric test in this thesis. The maximal values of both the Pearsonian r and phi coefficient are influenced by the differences in distributions. When the two distributions do not have symmetry or are not skewed in the same manner, the product-moment correlation does not reach its maximum. Maximal and minimal product-moment limits can be calculated on a computer, but existing programs will not ignore irrelevant blanks as will Data-Text. The choice of using phi, even on non-symmetric interval data by splitting at the median or other logical point, was in part governed by the ease of calculating approximate maximum values by graph.[1] Without quick analysis of the several hundred two-by-two tables calculated, the publication of this research would be delayed considerably.

---

[1] George A. Ferguson, Statistical Analysis in Psychology and Education (New York: McGraw Hill Book Co., Inc., 1959), p. 196.

The use of phi coefficient for reducing tables once having discrete, multinominal or ordinal data in one variable is accepted but not recommended.[2] It is essential to realize that the assumptions underlying the alternative procedures, tetrachoric r or point biserial correlation, do not allow use of extremely skewed distributions. Inasmuch as tau B[3] equals phi in a two-by-two table, the non-parametric interpretation of phi does have validity. Furthermore, it has been voiced that small cell frequencies do not lead to spuriously high coefficient values as in the case of the contingency coefficient. This tendency to lower, not raise, the coefficient values reflects the relation between phi and parametric procedures.

---

[1] The appropriate graph occurs in J. P. Guilford, Fundamental Statistics in Psychology and Education (New York: McGraw Hill Book Co., Inc., 1965), p. 337 and in William M. Meredith, Basic Mathematical and Statistical Tables of Psychology and Education (New York: McGraw Hill Book Co., Inc., 1967), p. 296.

[2] Ferguson, p. 196, mentions, "In practice it [the phi coefficient] is widely used when the two variables are obviously not discontinuous." Guilford, p. 354, suggests the use of the tetrachoric r or a formula for estimating the Pearsonian r.

[3] Tau B, an ordinal statistic, is discussed in Maurice G. Kendall, Rank Correlation Methods (New York: Hafner Publishing Co., 1962).

The phi coefficient is calculated by Data-Text using the following formula:

$$\text{Phi} = \sqrt{\frac{\chi^2}{N}}$$

Cramér's V coefficient

Couch[1] mentions that Cramér has suggested an adjustment for the phi coefficient when a table is not two-by-two. The V coefficient is identical to phi in the case of the two-by-two table. The investigator has failed to find a discussion of this coefficient in the open literature. The Couch reference does give the following computation formula based on the symbols in Figure Three:

$$V = \sqrt{\frac{\chi^2}{N\ (\text{Min } r-1 \text{ or } c-1)}}$$

where "Min r-1 or c-1" means the smaller of the two values, r-1 or c-1.

Ordinal Comparisons

Ordinal comparisons occur when the outcome of analysis depends on the order of categories of at least one variable.[2] Ordinal comparisons in two-by-two tables are reduced, by definition, to nominal procedures.[1] Most ordinal significance statistics are more powerful than nominal statistics in attempts to reject null hypotheses. However, most ordinal association measures are not associated with any powerful significance test. It is generally assumed that if a crossbreak is significant by nominal tests, it would be significant for the ordinal test (if one existed).

---

[1] Couch, p. 329.

[2] If one variable is not dichotomous, both variables must have a natural order.

Many ordinal tests were designed for a low total count of ranked subjects (teachers) and for few ties in ranking the teachers. In the vast majority of hypotheses, information is grouped providing many ties. Any ordinal test used in this thesis must conveniently allow for tied ranks, even if the ties were fortuitous. A second factor in choosing non-parametric tests was their availability in convenient computer programs.

Tests of Significance

Kolmogorov-Smirnov two-sample test

The Kolmogorov-Smirnov test is a highly sensitive test which detects any type of difference in distributions of two samples.[2] The test compares the largest difference in the cumulative distribution, D, to critical D values charted for various levels of significance.

For large samples, over forty teachers, the count of each sample need not be equal. However, for samples under forty-one the samples must be of equal size. The test cannot be made when one sample is under forty-one and the other over forty. Since it would be difficult to randomly discard the teachers' responses from a few hundred responses in order to equalize sample sizes to forty or less, most uses of this test have been for large samples.[1] Cumulative frequencies for large samples are not expressed as individual teachers (as with the small sample procedure); they are expressed as cumulative percentage. The difference in cumulative frequencies, D, is expressed as the decimal equivalent of the cumulative percentage distribution. For the .05 alpha level, the critical D is found by the following formula

---

[1] It is appropriate for tau B (ordinal) to equal the phi coefficient in two-by-two tables.

[2] The test is explained in full by Siegel, pp. 127-136, 279.

$$\text{Critical } D.05 = 1.36\sqrt{\frac{n_1 + n_2}{n_1 n_2}}$$

where n_1 and n_2 equal the count of the two samples.

The cumulative frequencies were requested from the Data-Text program entitled, Frequencies. Other computations were done by hand.

Significance of tau C, tau CS

Some ordinal comparisons do not possess the dichotomy on one variable necessary for the Kolmogorov-Smirnov test. Often these tables, having a multi-categorized independent variable, need an ordinal measure of association. It seemed appropriate to test the significance of an associational measure on the standard error of that measure, rather than by the standard error of another function. Stuart[1] has devised a conservative test of significance for Kendall's tau C[2] based on the upper bound of the sampling variance of tau C.

---

[1] By happenstance, the test using a multiple specifier in Table Twenty-two had small and equal samples.

Calculations were done by hand after receiving the value of tau C from the Data-Text program. The following formula was used to estimate the variance of tau C based on the distribution of cell frequencies, size of sample, and the least number of cells in a row or column:[3]

$$\text{Variance tau C} = \frac{2}{n}\left|\left(\frac{m}{m-1}\right)^2 - \text{Tau C}^2\right|$$

where n = total count in analysis and m = least number of cells in a row or column.

The maximum standard error is the square root of this variance. For a two-tailed test, the confidence interval at a .05 alpha would be

$$1.96\sqrt{\text{variance tau C}}$$

Measures of Association

A major problem of the analysis phase was finding a way to express the strength of association. If all the variables could have been

---

[1] Allen Stuart

[2] M. G. Kendall

[3] Stuart's article (p. 108) may have a typographical error, not observed in the calculated example of the same article (p. 109). His formula for the variance,

$$VAR_{tc} \leq \frac{2}{n}\left\{\left(\frac{m}{m-1}\right)^2 - t_c\right\}^2,$$

appears to be in error since tau C (t_c) can possess a negative or positive value depending only on the order in which one variable is listed.

assumed to be of symmetrical distribution, phi or Pearsonian product-moment correlations may have given well-understood magnitudes of association. With non-parametric tests, the scale values of various associational measures are not the same. On ordinal data, the relatively insensitive Crámer's V test yields a higher number than the more sensitive tau C. Although both have 1.0 as a maximum value, tau C inevitably looks weaker than higher valued measures.

To further complicate matters, no interpretation of the associational values is helpful in judging the magnitude of association, unless the reader is familiar with past studies involving the measures[1]. There is no logical way to convert the coefficients, and empirical conversion tables would require tabulation of many variations in cell distributions. For this reason, several associational values are given with the hope that the reader will recognize one of the measures.

Kendall's Tau statistics

Tau B

Tau B is a modification of the original tau statistic described in most statistics texts. Tau B is used where numerous ties in ranks exist, as in a contingency table. Tau B is valid for square contingency tables, and it equals phi when the table is two-by-two. Except for the two-by-two situation, tau B does not equal Cramér's V. The relations among the tau statistics and other correlational measures are discussed at length in Kendall.[1]

---

[1] For instance, a Pearsonian r of .70 is an excellent correlation; most readers recognize it as unusually high and accounting for 49% of the variance in symmetrically distributed variables. But consider a tau C of .25; what does it mean? Would the same data giving a Pearsonian r of .70 give a tau C of .25?

The Data-Text System computes tau B by the following formula:[2]

$$\text{Tau B} = \frac{2\,(S-D)}{\sqrt{(N^2 - \sum_i R_i^2)\;(N^2 - \sum_j C_j^2)}}$$

where S and D are defined by the following operation.

Take every conceivable pair of teachers and determine if the first teacher has a higher or lower rank than the second teacher on each of the two variables defining the rows and columns of the table. (Do not consider reversals of the teacher pairs. For instance, count AB once; do not consider BA as a different pair.) Assign the value, +1, to a pair in which the first teacher has a lower rank on variable one than the second teacher. If the first teacher has a higher rank than the second, the assigned pair value should be -1.[3] Do the same for the second variable. Now each pair of teachers has two values, one for each variable. Multiply these values so that a resultant value, +1 or -1, can be assigned to each pair of teachers. Now count the +1 pairs and call this total count, "S." The total count of -1 pairs will be called, "D."

---

[1] Kendall

[2] Use Figure Three as a partial key.

[3] The question of tied ranks becomes more mathematically involved and is not included in the definition of S given by Kendall. Tied ranks on both variables are considered in the coefficient.

Tau C

Tau C is an adaptation of tau B for use with contingency tables which are not square. The formula for tau C, using symbols previously defined for tau B and tau CS is

$$\text{Tau C} = \frac{2\ m\ (S-D)}{N\ (m-1)}$$

Both tau statistics are computed by Data-Text.

Gamma

The gamma statistic concerns itself with the S and D counts of the tau statistics. Gamma attains its maximum, ± 1.0, under more conditions than tau B. In a two-by-two table, any cell void of an observed frequency will cause gamma to equal one. This characteristic of gamma is due in part to the fact that gamma ignores tied pairs.[1] The formula for Data-Text computation is

$$\text{Gamma} = \frac{S - D}{S + D}\ .$$

Goodman and Kruskal originally defined gamma as "the difference between the conditional probabilities of like and unlike order, given no ties."[2] If there is a greater chance of like order than unlike order, there is a positive association.

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[1] R. H. Sommer, "A New Asymmetric Measure of Association for Ordinal Variables," American Sociological Review, XXVII (December, 1962), 802.

[2] Leo A. Goodman and William H. Kruskal, "Measures of Association for Cross Classifications," Journal of the American Statistical Association XLIX (December, 1954), 753.

Sommer's D

Sommer's D statistic[1] is related to Kendall's tau B and to the Goodman-Kruskal gamma. The magnitude of the coefficient is usually between tau C and gamma; one reason for this is that Sommer's D does consider the number of tied pairs of teachers on one variable. The formula given by Sommer[2] is

$$d_{xy} = \frac{S-D}{S+D+X_O} = \frac{S-D}{Y_U}$$

where d_{xy} = Sommer's D for the independent variable y and the dependent variable x and

where X_O = ties on the dependent variable and

where Y_U = pairs of observations not tied on the dependent variable.

In terms of Figure Three, Data-Text computes this statistic only when the rows represent the dependent variable; the formula is

$$D = \frac{2\,(S-D)}{N^2 - \sum_j C^2_j}$$

Sommer defines D as "the difference between conditional probabilities of like and unlike order, under the condition that we ignore ties on the independent variable..."[3] The ignoring of ties on the spatial variable raises the coefficient above the tau statistic.

---

[1] An execellent discussion occurs in Sommer.

[2] Ibid., p. 804.

[3] Ibid., p. 804.

Parametric Comparisons

Student's t-test, one-way analysis of variance, and point-biserial correlations are explained in most elementary statistics texts. These tests are used infrequently in the analysis of specific hypotheses in this thesis. The major hindrance to using these tests was the presence of extremely skewed distributions which probably represented the distribution in the population (if one considers this non-random sample representative of a population). Normalization of distributions was not considered appropriate.

It is important to realize that no teacher answered more than once to a question; each unit in an analysis is therefore independent, in the statistical sense of tests used. If teachers contributed data from several of their classes, giving different answers for various subjects and levels of students, the analysis would be entirely different -- if not too cumbersone to analyze.

BIBLIOGRAPHY [1]

Books and Pamphlets

Biological Sciences Curriculum Study. Laboratory Blocks in Teaching Biology. Edited by Addison E. Lee, David L. Lehman, and Glen E. Peterson. (BSCS Special Publication No. 5.) Boulder, Colorado: Biological Sciences Curriculum Study, 1967.

Caudill, William W. Toward Better School Design. New York: F. W. Dodge Corp., 1954.

Council of Chief State School Officers. 1965 Purchase Guide for Programs in Science and Mathematics. Boston: Ginn and Co., 1965. Educational Facilities Laboratories, Inc. Design for Educational T.V.: Planning for Schools with Television. New York: Educational Facilities Laboratories, 1960.

Engelhardt, N. L., Engelhardt, N. L., Jr., Leggett, Stanton. School Planning and Building Handbook. New York: F. W. Dodge Corp., 1956.

Ferguson, George A. Statistical Analysis in Psychology and Education. New York: McGraw Hill Book Co., 1959.

Grobman, Arnold B. et al. BSCS Biology -- Implementation in the Schools. (Biological Sciences Curriculum Study Bulletin No. 3.) Boulder, Colorado: Biological Sciences Curriculum Study, 1964.

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[1] This section lists those references cited in this thesis. A more comprehensive list of references, for those interested in further study, would be found in the qualifying paper, David Engelhardt, pp. 119-136.

Guilford, J. P. Fundamental Statistics in Psychology and Education. New York: McGraw Hill Book Co., 1965.

Hurd, Paul DeH. Science Facilities for the Modern High School. (Monograph No. 2, Bulletin of the School of Education, Stanford University.) Stanford, Calif.: Stanford University Press, 1954.

Kendall, Maurice G. Rank Correlation Methods. New York: Hafner Publishing Co., 1962.

Kerlinger, Fred N. Foundations of Behavioral Research. New York: Holt, Rinehart and Winston, Inc., 1965.

Meredith, William M. Basic Mathematical and Statistical Tables of Psychology and Education. New York: McGraw Hill Book Co., 1967.

National Council on Schoolhouse Construction. Guide for Planning School Plants. East Lansing, Michigan: National Council on Schoolhouse Construction, 1964.

National Research Council. Guidelines for Development of Programs in Science Instruction. Publication 1093. Washington, D. C.: National Academy of Sciences, 1963.

National Science Foundation. Science Education in the Schools of the United States. Washington: U. S. Government Printing Office, 1965.

Oregon, State Department of Education, The Division of Education Development. The Structure of Knowledge and the Nature of Inquiry. (A Report of the 1964 Oregon Program Workshop for The Oregon Program: A Design for the Improvement of Education.) Salem, Oregon: State Department of Education, 1965.

Richardson, John S. School Facilities for Science Instruction. Washington, D. C.: National Science Teachers Association, 1961.

Schwab, Joseph J. "The Teaching of Science as Enquiry," The Teaching of Science. Jointly bound with a lecture by Paul F. Brandwein. Cambridge, Mass.: Harvard University Press, 1962.

Selltiz, Claire, et al. Research Methods in Social Relations. New York: Holt, Rinehart and Winston, Inc., 1959.

Siegel, Sidney. Nonparametric Statistics for the Behavioral Sciences. New York: McGraw-Hill Book Company, Inc., 1956.

Sumption, Merle R. and Landes, Jack L. Planning Functional School Buildings. New York: Harper and Bros., 1957.

Woodburn, J. H. and Obourn, E. S. Teaching the Pursuit of Science. New York: Macmillan Co., 1965.

Articles

Brubaker, C. W. "Relation of Learning to Space and Vice Versa," National Association of Secondary School Principals Bulletin, XLVI (May, 1962), 197-200.

Campbell, J. A. "Chemistry -- An Experimental Science," The School Review, LXX (Spring, 1962), 51-62.

Cochran, W. G., "Some Methods for Strengthening Common χ^2 Tests," Biometrics, X(December, 1954), 417-451.

Finlay, G. C. "Physical Science Study Committee," The School Review, LXX (Spring, 1962), 63-81.

Goodman, Leo A. and Kruskal, William H., "Measures of Association for Cross Classifications," Journal of the American Statistical Association, XLIX (December, 1954), 732-764.

Hurd, Paul DeH. "The New Curriculum Movement in Science: An Interpretative Summary," The Science Teacher, XXIX (February, 1962), 6-9.

Martin, W. E. "Report of Recorder for Group III -- Unresolved Issues and Problems in Science Education Research and Next Steps for NARST," Science Education, XLIV (February, 1960), 30-32.

Martin, W. E., et al. "Facilities, Equipment, and Instructional Materials for the Science Program," Rethinking Science Education. (National Society for the Study of Education Yearbook LIX, Part 1.) Chicago: University of Chicago Press, 1960.

Sommer, R. H. "A New Asymmetric Measure of Association for Ordinal Variables," American Sociological Review, XXVII (December, 1962), 799-811.

Strong, L. E. "Chemistry as a Science in the High School," The School Review, LXX (Spring, 1962), 44-50.

Stuart, Allan. "The Estimation and Comparison of Strengths of Association in Contingency Tables," Biometrika, XL (1953), 105-110.

Unpublished Materials

Couch, Arthur S. "Data-Text System: Preliminary Manual." Cambridge, Massachusetts: Department of Social Relations, Harvard University, 1967. (Unpublished lithoprint not for general distribution.)

Engelhardt, David. "Space Requirements for Science Instruction: Grades 9-12." Unpublished Qualifying Paper, Harvard Graduate School of Education, Cambridge, Mass., October 1966.

Jones, Kenneth J. "The Multivariate Statistical Analyser." Cambridge, Massachusetts: By the author, available from the Harvard Co-operative Society, 1964.

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